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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *VACUUM GAUGE*

A new design of radium-type vacuum gauge is supplied with a number of ranges covering pressure measurement from 1000 to 0·0001 mm of mercury. The response of the gauge is said to be practically instantaneous, while the output signal to the meter is linear and proportional to the gas pressure. The signal is determined by the collection of gas ions produced by a constant flux of alpha particles emitted from a small sealed radium source, which is too small to constitute a health hazard. Essentially, all the ions produced are collected in either of two ionisation chambers, one of which is provided for high-pressure ranges and the other for low-pressure ranges. The ion current is amplified by a factor of 10^7 and is indicated by a meter or a recorder. A low-voltage collection field is employed, so that problems arising from contamination of electrodes are eliminated. The use of a special small chamber, located in the measuring head, excludes the possibility of non-linearity due to recombination of the ions in the high pressure ranges. This is a factor which has limited the applicability of previous gauges of this type. The volume of the sensing element has been kept small, so that the pressure in the element will follow more closely sudden pressure changes in small-vacuum systems. The minimum pressure that can be measured is limited by several factors, it is stated. Among these factors are the grid current of the electrometer tube, the response time constant, and the permissible contamination without loss of accuracy. The grid current of the electrometer tube sets an ultimate limit of about 10^{-6} mm as the lowest measurable pressure. This, however, would be attained with a response time constant of well over one minute.

● *TERMINALS FOR CERAMIC RESISTORS*

A recent invention is concerned with the bonding of metallic leads to non-metallic resistance material, and in particular describes the provision of a ceramic terminal composition for forming an integral ceramic structure with glass-bonded conductors such as thermally sensitive resistors. For such an application, the invention envisages materials composed of a glass-bonded, uniformly distributed metallic powder. The inventors state that it has been found that a material for the terminal contact surface, which has optimum characteristics from the electrical aspect, as well as from that of bonding with the material of the electrical resistor, is composed of about 70 to 89% nickel, about 8 to 29% boro-silicate glass, and about 1 to 3% alkaline earth borate glass, such as, for example, a magnesium borate glass. While nickel powder of about 325 mesh per inch is said to be preferable as the electrical conducting constituent, other metallic powders such as silver, copper, nickel-chrome alloy, or iron powder may be used with satisfactory results. The magnesium borate glass may consist of about 95% B_2O_3 and about 5% MgO, both of which are preferably ground to about 200 mesh per inch. A composition suitable for sintering at 1150° to 1300° F consists of 70% nickel, about 28% boro-silicate glass, and about 2% magnesium-borate glass. For sintering temperatures of 1300° to 1550° F, a composition of about 78% nickel, about 21% boro-silicate glass, and about 1% magnesium-borate glass is desirable. For sintering temperatures of 1550° to 1700° F, a composition of about 80% nickel, 19% boro-silicate glass, and about 1% magnesium borate glass is suggested. It is claimed that these materials are especially useful for providing terminals on resistance materials having either positive or negative resistance temperature coefficients.

● *SILVER-COATED JOINTS FOR ALUMINIUM CONDUCTORS*

A new process for silver-plating aluminium has been developed and is being used to eliminate joint failures which otherwise could be caused by the high-resistance aluminium-oxide film. Many thousands of sample bars are reported to have been subjected to evaluation tests including the following:—(1) Bonding strength between silver plate and aluminium at room temperature; (2) freedom from blistering at high temperature; (3) freedom from porosity; (4) protection against corrosion in humidity and salt spray; (5) ability to carry high momentary currents; (6) ability to withstand short-circuit forces; (7) ability to withstand severe overheating by current overload; (8) stability of performance on long-time cycling heat run. The bond between the silver plate and the aluminium has been found to be stronger than either of the two metals. Extensive endurance tests under high-humidity conditions have shown that greasing after silver plating solves whatever minor corrosion problems may exist with aluminium-to-aluminium and aluminium-to-

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The practical application of transistors

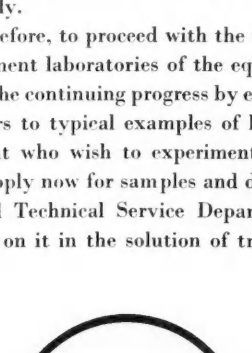
THE realisation of practical electronic equipments using transistors is dependent upon the success of three major development activities.

The first, which is basic work leading to transistor know-how, takes place in the research laboratories of the transistor manufacturer. In this field great progress has been made by Mullard, particularly in the control of material processing and purification. This is a prerequisite in the large-scale production of transistors of consistent performance.

The second development activity takes place in the transistor manufacturer's own measurement and application laboratory. Here, Mullard have energetically applied the experience, so far gained, to the initial transistor research work and produced samples of five types of transistor. These samples, the forerunners of a comprehensive range, will be available almost immediately.

It is now possible, therefore, to proceed with the third essential activity. This is in the development laboratories of the equipment manufacturer, who can contribute to the continuing progress by experimentally applying these sample transistors to typical examples of his problems.

Designers of equipment who wish to experiment with these new transistors are invited to apply now for samples and data. The experience of the Mullard Industrial Technical Service Department is available for those wishing to draw on it in the solution of transistor problems.



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copper joints in the great majority of switch-gear applications. Endurance tests under salt spray conditions have shown that an envelope configuration of silver plate, plus zinc chromate grease and paint, provides highly stable performance. Because many joints must be made between copper and aluminium conductors, addition of the silver plate does not introduce a new corrosion problem. In a high current test these silver-plated aluminium joints have remained undamaged at temperatures so high that the aluminium bars sagged because of their own weight. In a 1-year cycling heat run, no silver-plated aluminium joint was found to have increased its contact resistance significantly.

● *SILICON TRANSISTORS*

A recent report announces the development of a process for the production of pure silicon, and this may pave the way to more powerful and less bulky television, radio, and other electronic and electrical equipment. By the new process a large source of raw material for transistors, as well as rectifiers and probably other electrical parts, is becoming available. Moreover, the use of silicon is expected to broaden the scope of these developments because silicon can be used over a much wider temperature range than other materials available. Recent tests indicate that pure silicon used in transistors will compete with germanium in some cases. In fact, for many purposes silicon is the only known material that is practicable. This applies in particular to cases where components must operate at temperatures in excess of 170° F. Silicon remains useful at temperatures as high as 400° F, which means that, not only can it withstand more surrounding heat, but it can handle more power than other materials. In effect, it can handle several times as much power as, for example, germanium. It is also stated that the properties of silicon indicate that its use may improve the accuracy and precision in the functioning of electronic equipment. In the case of rectifiers, silicon would compete with selenium. The ability of silicon to withstand heat and handle greater power could mean that smaller rectifiers, with relatively higher capacities, could be developed.

● *PROTECTIVE FINISH FOR MAGNESIUM*

An electrolytically applied ceramic coating can be used as a protective finish on all magnesium alloys, including the rare earth alloys; it is generally used in an average thickness of 0·001 in. It is refractory and has excellent corrosion, abrasion, and heat resistance. The chemicals used in the alkaline bath solution are potassium hydroxide, aluminium hydroxide, trisodium phosphate, potassium fluoride, and potassium manganate. The parts to be treated need only be given a hot alkaline cleaning and a cold water rinsing, since the process itself possesses self-cleaning properties. The thickness of the coating varies with the time of treatment and the amperage used in applying the coating. The first phase involves a chemical union of the material with the surface layer of the magnesium, producing a surface of light oatmeal colour. This provides a good base for paint. Indications so far are that this layer, if left unpainted, is considerably inferior in corrosion resistance to the final coating built up to a thickness of 0·001 in. or more. The completed coating will scratch glass, and steel can be sharpened on the surface. Its hardness on Moh's scale is between 7 and 8. The coating provides the magnesium with a surface which is resistant to temperatures of 2500° F and higher. The dielectric strength of the coating is approximately 550 volts at network frequency, provided the coating is at least 0·001 in. in thickness. This insulation value indicates a highly non-conductive and impermeable coating. Since the insulating quality is so high, it obviously should be an effective means of preventing galvanic coupling action. Because the coating is ceramic in nature, its elastic properties are poor.

● *PROGRESS IN METALLURGICAL MICROSPECTROSCOPY*

For several years spectroscopists have been working on the problem of obtaining small area samples of metallurgical specimens in order to assist metallurgists in their task of identifying microstructures of specimens. One procedure evolved is based upon the utilisation of a microspark source, which is discharged through a fine quartz capillary onto the area to be analysed. Surface areas of 0·05 mm diameter were reported to have been successfully identified. In a modified version of this method, a small hole is drilled through a thin mica sheet to confine a spark to a small area of metal. In another approach to the problem, use was made of pointed graphite and metal counter electrodes for the analysis of segregates in metals. One of the difficulties encountered by spectroscopists in using methods of this kind has been the necessity for constructing special equipment A recently introduced method is claimed to have overcome this disadvantage and relies on the use of standard spectrographic equipment and a spark or arc source. This new method of identifying metallic constituents consists of drilling out the minute portion to be analysed, flowing collodion over the resulting chips, and transferring the collodion, together with the chips, to a pure carbon electrode for analysis in a standard spectrographic arc. Since 0·1 microgram of metal can usually produce a spectrum, drillings from a 0·001 in. diameter hole of equal depth can usually be identified as to major constituents. Drilling from 0·002 and 0·003 in. holes often provide more complete spectra and identification of high-alloy constituents. Several drilling machines, reported to be capable of using 0·001 in. drills, are commercially available.

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● *NEW SILICONE RESINS*

Foamed plastics, which represent a relatively new development in the field of plastics, can be used to advantage for thermal insulation, shock-resistant components, and light weight structural applications. Recently, interest in this material has been further stimulated by the development of several types of castable foamed plastics. With these types, the resin and a catalyst addition are poured into the mould or form and allowed to expand, conforming to the shape desired. Until recently, the plastic material used in these castable foams was limited mainly to phenolics or isocyanate or urea formaldehyde base resins, which are all thermosetting resins and, as such, will char in the presence of an open flame, although they will not support combustion. The range of applicability of castable foamed plastics has now been considerably expanded by the advent of castable foamed substances of the silicone resin type. It would appear that this type will prove particularly useful in applications for thermal insulation. Foams made of resins of this type have been exposed to temperatures of 700° F for over 20 hours with very little structural or dimensional change. Sections of this material, only one-half inch thick, can be brought to a red heat over an open flame without showing any significant decomposition. At 500° F, the material becomes resilient and loses a considerable amount of its compressive strength, so that it can be formed to the desired shape before the final cure. A similar silicone resin, also available, is a rigid thermosetting material with good compression strength; it retains a high percentage of its initial strength when heated to 500° F.

● *MAGNETIC TAPE CONTROL OF MACHINE TOOLS*

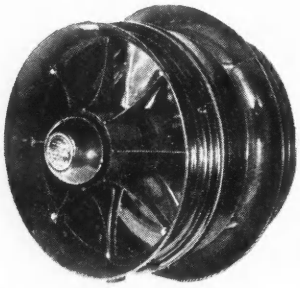
A record playback control system is now being developed in which a machine tool or process cycle is directed in accordance with information stored on a magnetic tape. It is estimated that in the case of a milling machine, used in the manufacture of self-reinforced skin structures of jet aircraft, the tape control system will double the production speed of the machine tool. The industrial type multiple channel tape recorder used in the new control system is similar to equipment employed in the entertainment and broadcasting fields, except that it records motion instead of sound. It will thus serve as a magnetic memory for the machine on which it is installed. In operation, a skilled machinist or a tracer control mechanism will run the machine through a series of motions to produce the first piece of work. These motions are translated into electrical signals by means of selsyns and are recorded on the magnetic tape through an electronic circuit. Non-productive motions, such as tool setting, gauging, template changing, and stop settings, are not recorded on the tape. When the tape is played back through the machine, it automatically duplicates the original motions of the machine tool and produces a part exactly similar to the one made while recording. Repeat orders can be produced economically by taking the specified tape recording from a file and inserting it into the control mechanism. Studies are now being made of the possibility of using an electronic computer to convert numerical data into the electrical signals recorded on the magnetic tape. This would eliminate the first manual machining operation.

● *NOVEL GAS TURBINE PLANT*

In most of the known gas turbine processes the high temperature of the driving gas imposes a severe punishment upon the turbine blade material. It is therefore necessary to reduce artificially the temperature of the driving gases, for example, by the admission of cooler air, which obviously causes considerable losses in cycle efficiency. It has already been proposed in cases where solid fuels and fuels with high ash content are to be burned, to connect the turbine in front of the combustion chamber, in order to protect the turbine blades against wear by fly-ash, but this arrangement has certain inherent disadvantages in other respects. A recent patent describes a method by which these disadvantages can be overcome. In a turbine cycle of this type, the compressed air delivered by the compressor is passed through a heat exchanger in which it is heated by heat absorption from the hot gases of a combustion chamber of the oscillatory gas-column type discharging directly into the heat exchanger. The heated air is then passed into the turbine, from which it is discharged into the combustion chamber, where it is used as combustion air and from which the products of combustion are then passed into the heat exchanger, as already explained. In the combustion chamber, gas oscillation is effected by the production of positive pressure waves travelling towards the open end of the combustion chamber, while a flow in the opposite direction towards the inlet of the combustion chamber is prevented by means of a non-return throttle member. At the open end of the combustion chamber, the advancing positive pressure is converted into a returning negative pressure wave, which draws fresh air into the combustion chamber for the subsequent cycle, and also causes ignition of the newly formed mixture.

● *MAGNESIUM ALLOYS WITH THORIUM CONTENT*

It is reported that aluminium alloy castings may soon have to compete with magnesium alloy castings containing thorium. Although thorium is an expensive alloying element, preliminary research appears to indicate that the cost factor may be



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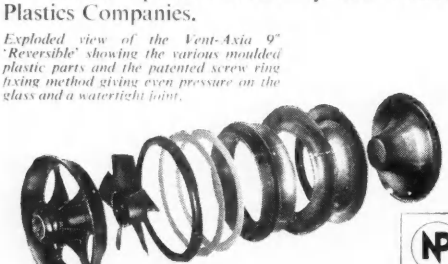

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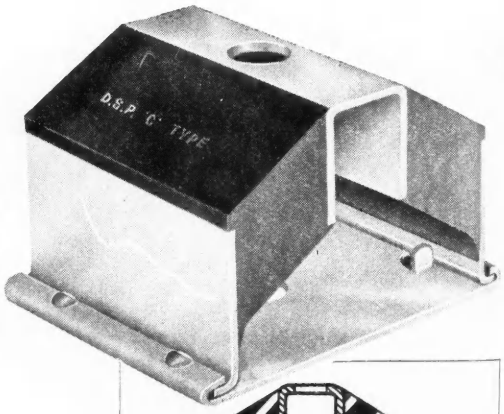

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outweighed by the outstanding mechanical properties which thorium imparts to magnesium alloy at ambient and elevated temperatures. In fact, the claim is made that these alloys can replace aluminium alloys, using the same sections. Foundry difficulties are said to be confined to metal preparation, and sound castings have been obtained, which have uniform properties and which are unaffected by section thickness. Alloys containing 2 to 3% thorium show good ductility and remarkable stability of properties after heating. Experience suggests that sand castings can be formed by hot or cold work and can still retain required mechanical properties, even in a welded assembly. The claim is also made that satisfactory repairs or assemblies can be made by welding. Another consideration is that unlike the cerium rare earths, thorium is not lost by reaction with chloride fluxes, while sudden, heavy scrap loads can be recirculated without loss of the most expensive component. For creep resistance, a magnesium base alloy of 3% thorium, 2·3% zinc, and 0·7% zirconium has been used. Another magnesium alloy contains 5·8% zinc, 1·9% thorium, and 0·7% zirconium. Production castings of gas turbine components, which required about 400 lb of molten metal, have been made. Castings were poured at 1350° F and risers were topped at 1400° F. No burning or excessive oxidation was encountered. The castings were clean, free from dross, and showed no signs of shrinkage porosity, though the overall shrinkage was increased.

● *LUBRICATION OF BALL AND ROLLER BEARINGS AT HIGH SPEEDS*

A recent research paper deals with the lubrication aspects governing the performance of rolling bearings operating in the speed range of 6,000 to 30,000 rpm and under radial, thrust, and combined loadings. Most of the work was carried out on standard ball bearings of 2-in. bore. Three different test machines were used. These machines were especially designed to allow examination of the following factors :—Effects of variation in oil feed, including reduction of oil feed to zero ; a comparison of various methods of lubricant supply ; and the influence of viscosity and boundary properties of the lubricant. In the first of these machines, two nominally identical ball bearings are mounted on either side of a collar on the high-speed shaft and subjected to thrust load by annular pistons under oil pressure. In the second machine, the hydraulic thrust loading system is replaced by spring-loaded levers forming a "nutcracker" system forcing the bearing housings together. The third machine was designed primarily for work on bearings under radial load only. In general, the criteria of bearing performance were temperature rise and friction. Bearing life was not considered, except where it was determined by instability of thermal conditions, since, under thermal equilibrium, bearing life is largely dependent on factors other than lubrication. The investigators conclude that, provided the bearing housings are adequately drained, the rate of oil supply and the method of lubricating high-speed rolling bearings are not critical, and that lubricating oil can be used as a very effective coolant with no appreciable increase in friction. Viscosity of lubricants has little direct effect on performance, but there appears to be a case for good boundary lubricating properties, particularly at elevated temperatures and under combined radial and axial loading.

● *NOVEL ELECTRICAL MEASURING SYSTEM*

A recently published patent specification describes a very simple and highly ingenious magnetic device, which appears to hold considerable promise for widespread applications in indicating, measuring, and recording instruments. This novel device comprises a permanent bar magnet, which is pivotally mounted for rotation about an axis coinciding with the magnetic axis of the bar. One electrical terminal is arranged at or near one end of the magnet and a second terminal is arranged on the side surface, midway between the ends of the magnet, so that the electrical path through the magnet has a radial component, together with a closed electrical circuit between the terminals. This feature is of basic importance, since it is the radial component of the current path which, by interaction with the magnetic flux, is responsible for production of a torque. The permanent magnet is preferably made of an anisotropic aluminium-cobalt-iron alloy and is conveniently shaped in the form of a cylinder able to rotate about its central longitudinal axis. When incorporated in indicating and measuring instruments, etc., the terminals will be made of hairsprings, which, in addition to conducting the electric current, will also supply an appropriate counter-torque, as is usual in measuring systems in which indication takes the form of deflection of a pointer over a dial. In the new system, the deflection will be proportional to the current flowing through the magnet and to the magnet strength, and, what is important, the relationship between the deflecting torque and current magnitude will be linear. It is claimed that this device has considerable advantages over the conventional moving-coil or moving-iron system used in electrical instruments. Moreover, considerations of mechanical clearances are eliminated.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

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Compound Gas Prime Movers

By J. SHAPIRO.

The gas turbine occupies an important place in present-day prime mover development. From a more general point of view, the advent of the gas turbine in the realm of practical engineering has helped to focus thought on the thermodynamics of the gas cycle and on the similarities and distinctions between various mechanisms by means of which the processes of the gas cycle are performed.

WHEN discussing thermodynamic principles in relation to mechanical means, it is useful to recall an account of the early history of Rudolf Diesel's invention. It is said that he was animated by the desire to embody the most efficient and perfect thermodynamic cycle, namely the Carnot cycle, in a prime mover using a gaseous medium. Translated into pressure-volume terms the Carnot cycle, performed on gas, looks horribly " thin." In fact, Diesel could not get his engine to move itself, let alone anything else. The embodiment of the Carnot cycle was associated with friction losses greater than the power derived from the process. Thereupon, Diesel began to " fatten " his diagram by introducing heat addition at constant pressure and so, it is alleged, the diesel engine was born.

In theory, of course, the ideal thermodynamic cycle for transforming heat into work is the Carnot cycle formed by two isothermal and two adiabatic processes. However, when a substance with the properties approaching those of a perfect gas is the working medium, such a cycle cannot even be the goal of practical engineering. Allowing for some over-simplification, the ideal gas cycle is the " ideal constant-pressure cycle," consisting of two isothermal and two constant-pressure processes. It has been pointed out that, when interchange of heat between portions of the working medium at different stages of the cycle is admitted, such a cycle approaches the Carnot cycle. Assuming that perfect heat exchange can be accomplished in a gas cycle of the ideal constant-pressure type, this cycle becomes thermodynamically identical with the Carnot cycle.

It is important to realize that, when there is no heat exchange, the constant-pressure cycle forms a separate standard of excellence, a standard most appropriate to prime movers using gas as a working medium. The reason for this is that all prime movers must be embodied in mechanisms and structures whose capacity is determined by the resistance of their materials to temperature and pressure. Furthermore, the working medium must be drawn from a source of ambient temperature and pressure. Thus, it is obvious that the most efficient method of arranging the working cycle of a prime mover is to maintain it in accordance with the highest temperatures and pressures permissible and the lowest temperatures and pressures available.

For the sake of an orderly approach, it is advisable to subdivide the field of compound or composite prime movers into several parts. The appropriate dividing lines are, on the one hand, the introduction of a working medium which undergoes a change of phase during its working cycle (vapour-liquid systems), and, on the other hand, the use of heat interchange. Work with more than one medium in a single plant introduces an entirely different degree of complexity than work with different types of mechanism using the same medium. Heat interchange, as distinct from the absorption or rejection of heat from combustion or by liquid cooling, involving, as it does, heat transfer at a vanishing temperature differential between two gaseous media, requires major engineering plant of its own, and leads to large-size installations. It is therefore proposed to devote this review to the compounding of gas cycle machinery, excluding vapour cycles, and without heat exchange between two gaseous media.

It is sometimes held that objections to the inclusion of vapour cycles and heat exchange can be applied equally to the mixing of heat-engine elements of different types. Indeed, all original developments of gas prime movers were actuated by the desire to replace the inevitable complexity of steam plant by machinery combining all the processes of the working cycle within a single unit.

The constant-volume process, from the point of view adopted here, is simply part of a cycle which does not make full use of the maximum pressure permitted by the nature of the mechanism and its materials. The compound gas prime mover is not primarily intended for the embodiment of gas cycles fundamentally different from the standard cycle of the simple constant-pressure gas turbine.

What distinguishes the gas turbine from other gas engines is not the gas cycle, but the mechanical elements by which the potential energy of a compressed gas is converted into mechanical work.

The departure from the pure " rotating-flow machine " as the only type of converter between fluid energy and mechanical work, introduces a variety of separate principles not always appropriately distinguished. Firstly, there is the flow principle versus the displacement principle. Secondly, there is the rotating motion as opposed to a translational motion. Thirdly, a machine may produce fluctuating (intermittent) or continuous motion.

Many combinations of these three separate features are possible and have been attempted. A few combinations are impossible, such as translational continuous motion. Some are of a wholly academic or impracticable nature, such as the flow principle associated with translational motion. This elimination leaves only a few combinations of practical merit.

In this context it is important to note that the displacement principle is inherently more suitable for dealing with high pressures than the flow principle and that the efficiency of compression by displacement is independent of the volume flow. The limitations upon compression in rotating-flow machines are associated with flow phenomena, such as flow separation and shock, leakage, the shape of blading, skin friction, high rotational speed, and the number of stages. Moreover, every rotating-flow compressor has an unstable region of operation (surging). The displacement compressor has its own limitations, which differ from one type to another but, without attempting a general demarcation of its practical field of application, pressure ratios up to 40 can be achieved in a single piston unit in instantaneous compression. In contrast with flow machines,

the important limitation on volume is, in practice, the size and weight of the displacement unit needed for large volume flows, whilst there is virtually no limit on small volume flows.

The second fundamental point is that an intermittent device can preserve a much larger temperature drop between the maximum temperature of the fluid medium and the maximum temperature of the wall in which it is confined than a continuous device, provided that in both cases the walls are equally cooled and the fluctuations of the intermittent device are fast enough. In practice this is true of all reciprocating gas engines. The phenomenon is due to sluggishness of heat transfer and conduction, and simply means that, owing to this delay, a cooled wall in contact with a fluid of fluctuating temperature assumes a temperature corresponding to the mean temperature of the fluid and not its maximum temperature.

This situation is fundamental and is not related to constructional difficulties of cooling, which are often an additional drawback of high-speed rotating-flow machines.

The gas-turbine designer is accustomed to view problems of the temperature resistance of materials not so much in terms of temperature and pressure as in terms of temperature and stress created by centrifugal loads. For the purposes of this discussion, it can be assumed that the temperature in question is that at which a given set of requirements, expressed by stress and life, has to be met. Speaking very broadly, basic advances in the creation of new temperature-resistant materials would ultimately improve both rotating-flow machines and displacement mechanisms.

The displacement principle can be profitably applied in some gas turbine installations by the complete or partial replacement of a flow compressor by a displacement compressor, still leaving the whole of the expansion to the turbine. This is a logical step, because, of the two, the compression process is the more difficult to accomplish, when a combination of small output, high pressure, and high efficiency is necessary. Displacement compressors in conventional engineering practice can be divided into three classes :—The most common is the reciprocating piston compressor driven by a shaft through a crank mechanism. The sliding-vane rotary compressor is extensively used, but no rotary piston compressor has yet become a practical machine. Finally, there is the rotary compressor, in which the displacement is caused by kinematic intermeshing of two rotating bodies. Displacement compressors belong to a separate branch of engineering, without a detailed study of which it would be impossible to discuss intelligently the potentialities of different types for gas-turbine installations in general. In practice, the only displacement compressor developed seriously for this application is the Lysholm compressor, belonging to the last of the three types enumerated, this being a continuous rotary displacement device.

The next step in the introduction of displacement devices into gas turbine installations is a division of the thermodynamic cycle into two or more parts. That part of the cycle associated with high pressures and temperatures and small volumes is appropriately handled by displacement mechanisms, usually of the intermittent type. The remainder of the cycle, associated with large volumes (and velocities) and low pressures and temperatures, is most efficiently performed by a rotating-flow machine.

The purpose of such a subdivision is, in the first place, the attainment of a compromise between the two extremes. If we sum up the present situation of piston and turbine gas engines by saying that the former produce prime movers of high efficiency and moderate specific output and the latter those of moderate efficiency and high specific output, it is natural that in some applications intermediate magnitudes of efficiency and output should be sought. Often of more importance, however, are the properties of the prime mover, apart from efficiency and specific output. Among these, the main concern of power engineers is with the following :—Maintenance of efficiency over a range of partial loads; the starting, control, and reversing facilities; the form in which mechanical energy is available (high or low speed, constant or variable torque-speed characteristics); the influence of atmospheric conditions on output, efficiency, and operation; the availability of overload capacity; the architectural and service facilities required by the installations; the flexibility of layout in confined spaces and of break-down for transport; and finally the facilities for and cost of maintenance. In enumerating these requirements a specified degree of reliability is naturally taken for granted.

Since displacement mechanisms are unable to deal with large flow volumes, all gas prime movers relying entirely on displacement converters must cut their gas cycles short of the large volumes resulting from complete expansion. Thus, incomplete expansion leaves recoverable energy in the exhaust of piston gas engines. Gas turbines are often used to complete the expansion under the heading of waste heat utilisation. This practice suggests that the compound installation is capable of embodying a better approximation to the ideal thermodynamic cycle and consequently has an inherent advantage over both pure types of machine and not merely the capacity of achieving a compromise between the advantages and disadvantages of either.

The practical attainment of these theoretical potentialities of compounding is associated with so many additional factors that no general proposition is easy to uphold. It is, however, undeniable that another weapon in the armoury of the power engineer holds potentialities of improvement not otherwise available. In practice, no compound engine installation has so far been able to claim an efficiency exceeding that of the best prime mover, i.e., the unsupercharged four-stroke compression ignition reciprocating engine (diesel). However, compound gas engine installations are in their infancy and may well develop faster than either the pure gas turbine or the pure reciprocating machine.

Nevertheless, even the few compound installations already in operation have achieved a combination of qualities far beyond a mere compromise between their elements. For land and marine duties the free-piston turbine combination can claim an efficiency equal to that of the best diesel engine, together with a specific output equal to that of the simplest rotating-flow gas turbine plant, quite apart from other outstanding qualities. In a different way, the same applies to another practical compound scheme, embodied in the Napier "Nomad" engine. It must be concluded, therefore, that among the innumerable alternatives of compounding, there are some in which the elements co-operate beneficially to produce a result better than could be expected from the individual elements.

The classification of the numerous types of compound prime movers, many of which have remained in the suggestion box, or at most in the project stage, is best undertaken firstly by the extent of the subdivision of the working cycle, and secondly by the nature of the mechanical interconnection between the elements of the compound installation.

Starting with the turbo-supercharged piston prime mover, we have an arrangement in which only a small part of the total energy transformation is accomplished in the rotating flow components. The most common representative in this group is the Büchi system, applicable to a four-stroke diesel engine. In this system the exhaust gas from the engine is released before full expansion has taken place and made to drive the gas turbine which, in turn, drives the supercharger. In practice, supercharging greatly increases the specific power of the piston engine but has little effect on efficiency. The rotating-flow elements have no mechani-

cal connection with the power output of the diesel engine, and hence the operation of the system depends on the availability of adequate power in the exhaust to drive the supercharger under all conditions, especially those of partial loads.

Recently, the system has been critically re-examined, both by analysis and by experimental measurements, and it has been found that in many cases the engine suffers excess pressures which have been responsible for some adverse results. It is now an accepted premise that supercharging must be judged by its effect on engine performance, efficiency, and life, with the proviso that a given maximum pressure is not exceeded. Thus, the Miller-Nordberg supercharging system seeks to ensure in operation a controlled limitation of maximum pressure.

It is well known that two-stroke diesel engines cannot be successfully supercharged in this manner and that in certain states of operation a contribution from engine power is required.

The turbo-supercharged diesel engine cannot really be considered as a compound prime mover, because in such a plant the reciprocating piston engine performs the major part of the energy transformations. Several designers have endeavoured to ascertain the results of increasing the degree of supercharging to a point where the rotating and reciprocating components perform energy transformations of the same order. At some point the maximum pressure in the diesel cylinder is exceeded. Beyond this point, if the supercharging pressure is further increased, the diesel engine begins to lose its share of the power delivered, but excess power appears on the supercharger shaft. Consider the extreme condition in which the diesel engine has lost all its power and the supercharger shaft delivers the whole power of the installation. In this condition the diesel engine acts merely as the equivalent of a combustion chamber in a gas turbine. It is obviously distinguished from a constant-pressure combustion chamber by the fact that the gas in it takes part in a compression and expansion process. Externally, such a " combustion engine " will differ from a combustion chamber by raising the pressure of the gas. In other words, the combustion outlet pressure will be greater than its inlet pressure. The same result would be obtained in a so-called explosion gas turbine. In practice, neither the piston-type nor the pistonless combustion engine has so far been found attractive and its discussion in this context is of interest only to indicate a gap in the pattern of classification. The reason for this lack of interest is mainly the superiority of other systems mentioned below. The difficulty is fundamental. In this scheme the energy conversion in the reciprocating component, instead of delivering excess power above that of a constant-pressure combustion chamber, increases the pressure energy of the gas. Since the pressure level is raised, mixing is impossible and the whole mass flow of air must pass through the reciprocating component.

The next category of compound prime mover is known as the gas generator engine. Here, a piston engine drives a compressor, by means of which the air is compressed before entering the power cylinder. The exhaust of the engine, still at an elevated pressure, is used to drive a gas turbine, which delivers all the useful power. Some air from the compressor is by-passed to the turbine, after mixing with the heated exhaust gas from the power cylinders. There may, or may not, be additional constant-pressure combustion between the piston engine and the turbine. The free-piston gas generator is the most important representative in this group.

Finally, all three elements, namely compressor, piston engine, and turbine may be intergeared, so that the useful power is developed partly by the piston engine and partly by the turbine. This combination is known as the " geared " compound engine.

There are, of course, many additional variations of these schemes. For instance, the compressor may be split into two or more stages, of which one is associated with the turbine and the other with the reciprocating engine. The turbine may also be split into a separate power turbine and another turbine, used only to assist in driving the compressor. The aggregate may be supercharged by a mechanically independent compressor set, if the variation in atmospheric conditions, such as is encountered by aviation engines, is the main purpose of supercharging.

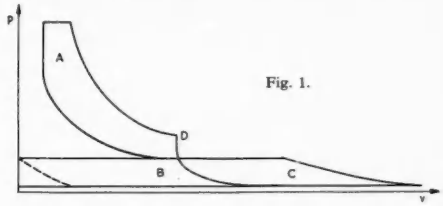

Fig. 1.

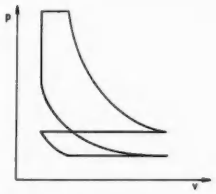

Fig. 2.

Among proposed schemes with subdivided compression, there is one with a special distinction from the thermodynamic point of view, the discussion of which clarifies some problems of compounding. The cycles of the gas generator scheme are shown in Fig. 1 (not to scale), representing pressure-volume diagrams of the three separate elements. The reciprocating engine diagram is shown at (A), whilst (B) and (C) are the cycles of the compressor and turbine respectively. If the compressor is also of the reciprocating type, its diagram is modified by the broken line. The important point about the engine diagram is the incomplete expansion at (D), sometimes known as the " toe " of the diagram, and referred to as the " toe loss." Fig. 2 shows a cycle avoiding the toe loss, as proposed by Metropolitan-Vickers. This calls for two compressor stages, the first stage to deliver air to the engine cylinder and to the second compressor stage. The engine exhausts at the delivery pressure of the second compressor stage and the two deliveries are mixed to reduce the temperature of the exhaust. An engine embodying this cycle must necessarily be a four-stroke engine.

A survey of the performance of compound power plants in general terms can be given only if many assumptions are accepted as sufficiently representative to preserve the generality of the study. Some of these are universal in reciprocating engine practice, but others need emphasis because they are subject to appropriate design and development. The latter can be stated as follows :

(1) Maximum permissible cylinder pressure is limited to 1300 psia.
(2) Compressor efficiency is 80%.
(3) Turbine efficiency is 85%.
(4) The engine is a two-stroke engine with scavenging consuming 30% excess air.
(5) The pressure of the air drops by 10% between compressor outlet and engine exhaust.
(6) The loss due to incomplete expansion of the engine (" toe loss ") is taken into account, and additional curves are given, based on the assumption that by some means this loss is entirely recovered.

On these premises, the curves in Fig. 3* (see p. 36) give the specific fuel consumption with and without toe loss recovery, the specific power per lb of air under the same assumptions, and the air fuel ratio, plotted against the "working pressure," i.e., the turbine inlet pressure. In these curves, the gas generator and the geared type of compound engine are compared. The superior efficiency of the geared type at a low working pressure is nothing more than an indication of the superiority of the reciprocating engine. It is interesting to compare these with the actual test results of an existing free-piston gas generator installation. The specific fuel consumption of the real gas generator is about 10% better than that based on the assumptions made at this point. The special features of the free-piston gas generator responsible for its superior efficiency have already been discussed.†

(*Concluded on page* 36)

*Based on Fig. 13, p. 657, of *S.A.E. Journal*, Vol. 3, No. 4, October 1949.

†*The Engineers' Digest*, June 1953, pp. 201-203.

U. S. A.

New Developments in Liquid Heating of Plastics-Processing Machinery

By P. L. GEIRINGER and F. HASSELRIIS. (From *Mechanical Engineering*, Vol. 75, No. 12, December 1953, pp. 957-962, 986, 11 illustrations.)

This paper explains the superior ability of liquid heat carriers to meet the increasingly stringent requirements of the plastics industry. The principles which must be understood in order to gain the full advantages of the application of liquids are reviewed briefly, and the special requirements of calenders, extruders, injection-moulding machines, and plastics presses are discussed.

NEW plastics and higher production speeds create so much frictional heat in plastics that, for proper control, both cooling and heating must be applied, with a smooth transition from one to the other. Water cooling in combination with steam heating has not produced good results and has caused considerable damage to equipment. Liquid heat carriers provide smooth control from full heating all the way to full cooling, and this accounts to a large extent for their popularity today.

They offer the following major advantages to the plastics industry :—

(1) Uniform temperatures over the entire heat-transfer surface.
(2) Full-range heating and cooling over wide temperature ranges.
(3) Accurate temperature control with rapid response.
(4) Separate control of a number of individual temperature zones with one compact heating and cooling unit.
(5) Programme temperature control of heating and cooling.

The heat-transfer requirements of modern plastics machinery cannot be met by superficial engineering. The cost of properly designed heat-transfer equipment is usually small compared with the losses resulting from poor production. While liquid heat carriers have much to offer, their application requires an understanding of certain fundamental principles and a sound background of experience.

LIQUID HEATING DESIGN CONSIDERATIONS.

Selection of a Suitable Liquid Heat Carrier. The liquid heat carrier selected must have a range of temperature sufficiently great to permit maintaining the anticipated plastics-processing temperatures, and satisfactory heat-transfer properties. Table I lists a few representative plastics materials and their approximate extrusion temperatures. Some important plastics have processing temperatures well in excess of 500° F.

TABLE I. EXTRUSION TEMPERATURES OF PLASTICS.[1]

Material	°F
Vinyl	350-390
Ethyl cellulose	370-440
Polyethylene	400-530
Fluorethene	550-600
Nylon	450-625

Some currently used liquids, together with the approximate temperature ranges in which they have been applied, are given in Table II.

TABLE II. LIQUID HEAT CARRIERS.

	Recommended operating temperatures °F	
	Minimum	Maximum
Water	40	400-450
Heat-transfer oils	100	500-550
Diphenyl chlorides (Arochlors)	50	550-600 (Hydrotherm 500)
Aryl silicates	0	600-650 (Hydrotherm 700)
Diphenyl, diphenyl-oxide mixture (Dowtherm)	70	650-700
Tetra cresyl silicate	50	750-800
Eutectic salts	320	1000-1200

It is difficult to recommend maximum operating temperatures for all liquids, because these limits depend not only on the nature of the liquid, but also on the design of the equipment, especially that of the heater. The heater must be designed carefully to prevent hot spots from causing decomposition and other difficulties. Forced-circulation heaters are especially satisfactory for this purpose. The heat-transfer properties of the heat carrier, such as the specific heat, viscosity, density, thermal conductivity, and the range of practical heat-transfer coefficients, must be considered as well as pumping requirements, leakage characteristics, decomposition, corrosion, etc. Water has the best heat-transfer coefficient and the best overall properties, but for high temperatures, over 450° F, excessively high pressures are required. The other liquids listed in Table II may be used at low pressures. Heat-transfer oils generally have the poorest heat-transfer properties and the highest viscosities at lower temperatures.

Design of Circulation Passages. The design and arrangement of the liquid passages must be considered carefully if the full benefits of liquid heat carriers are to be obtained, as in the design of any heat exchanger. The quantity of liquid which should be circulated through the passages depends upon the amount of heat that must be added or removed, the temperature drop which the fluid may be allowed to suffer between entering and leaving the machine (as determined by the permissible temperature variation of the heat-transfer surface), and the specific heat of the liquid. The cross-section of the circulation passages should be determined by the liquid velocity which will result in the optimum heat-transfer coefficient. High liquid velocities must be obtained in the passages, where good heat transfer is needed in order

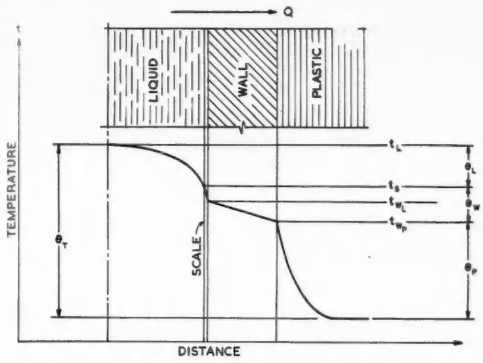

Fig. 1. **Temperature gradients across heat path.**

to obtain high film coefficients and correspondingly low temperature drops across the heat path.

Fig. 1 shows a representative diagram of the temperature gradient across the heat path. Usually, the temperature drop across the metal wall is relatively small, making it comparatively easy to obtain accurate temperature measurements in this region. The temperature difference θ_t determines the amount and the direction of the heat flow in accordance with the equation $Q = U\,A\,\theta$, where the area A and the overall coefficient of heat transfer U are fixed. For satisfactory temperature control it is not good practice to vary the liquid velocity, but rather to maintain high velocities and correspondingly a high film coefficient on the liquid side at all times. Some liquid-heating control systems vary temperature and heat transfer by throttling the rate of liquid flow. In these systems the surface uniformity suffers and the control becomes sluggish, resulting in a poor control of temperature.

It will be noted from Fig. 1 that a substantial temperature drop can occur in the scale. This can be avoided by the proper use of liquids, since liquid systems are closed and impurities cannot enter the circuit from the outside.

Plastics-Processing Machinery.

Processing of plastics requires a number of basic steps. The first is mixing or compounding. Next, the plastic must be "plasticised" or rendered into a plastic and homogeneous state at a higher temperature. After shaping or forming, it must be cooled. The mixing of plastics often requires considerable kneading of the plastic mass, with simultaneous heating. Plasticising also requires kneading or mulling, together with heating, in order to produce a uniform plastic temperature. In some cases the plastic is viscous enough to be heated mainly by the frictional work done on it, while in other cases most of the heating must be done by heat conduction. Screw extruders and calenders often produce so much frictional heat that cooling of the material is required. In the case of extrusion, cooling is important around the feed hopper, in order to keep the mass stiff enough to permit the feed screw to force it through the machine.

During the plasticising process, the plastic mass must be raised to a closely specified temperature, in order to meet the requirements of the forming process, and to prevent damage to the plastic as a result of overheating. Injection moulding requires that the plastic mass be injected into a cooled mould at a viscosity, temperature, and pressure sufficient for it to reach all parts of the mould before solidification takes place.

Thermoplastic materials require a final cooling phase, which in some cases is critical, since excessively fast cooling may produce stresses in the finished plastic. Thermosetting plastics require a curing phase, during which the setting reaction takes place. Careful temperature control is needed in the mould during this phase.

Each type of equipment and each type of plastic evidently require heating and cooling at various phases of the process of conversion of the raw plastic into the finished product. In some types of equipment the plastic moves, passing a series of temperature regions, each having its own temperature-control problem. In other cases the plastic is retained in a container and the adjacent heat-transfer surfaces are subjected to a series of different temperatures in order to process the plastic. A more detailed discussion is required, to bring out the special requirements of each type of machine and plastic material.

Calenders.

Four-roll calenders are used currently for calendering plastics such as vinyls. The plastic is forced into banks before being forced through the nip between pairs of rolls. In these banks substantial frictional heating is created in the plastic. This, together with heat conducted from the roll, produces the proper processing temperature. If the roll speeds are higher than about 45 yards per minute, so much excess frictional heat is produced in many vinyl compounds that cooling is required. Depending upon the operating conditions, each roll must be maintained at a different temperature, which may represent either heating or cooling. High-temperature water has been found to provide accurate control of heating and cooling for each calender roll. Steam cannot provide successful heating and cooling, while water injection has not been found to be satisfactory.[2] Steam-heated plastics calenders therefore are being converted rapidly to use high-temperature water. New designs have completely abandoned steam heating.

Drilled rolls are now going into nearly all new calenders, permitting utilisation of the full roll width[3]. Cored rolls also have been found to operate satisfactorily with high-temperature water, when adapted properly, although drilled rolls are preferable.

For the processing of most vinyl films, roll temperatures of 300 to 350° F are required, making high-temperature water the most practical heat carrier. In general, a deviation in the proper roll surface temperature greater than 5° F cannot be tolerated.

Design of Circulation System. Fig. 2 shows a circuit for heating and cooling of calenders, which also may be used in other plastics applications. Two fluid circuits are provided, one passing through a heat source, which may be heated electrically, by steam, or by direct fire, and the other passing through the cooler. These two water circuits are made available in front of each roll or zone and may be mixed in accordance with the quantity and direction of heat flow to or from the roll, to maintain any required temperature manually or automatically. If heat has to be absorbed, water at a temperature below the roll temperature is admitted; if heating is required, the temperature of the water is above the roll temperature. It may or may not be necessary to provide a separate pump for each control circuit. However, such a pump makes it possible to maintain a constant rate of circulation through the circuit at all times, permitting a smooth transition from heating, to neutral, to cooling. Fully automatic systems of this type can maintain temperatures of one roll to a tolerance of 1° F.

Temperature Control. Temperature control presents one of the greatest problems facing the plastics industry to-day. The difficulty does not lie in a lack of accurate instrumentation, as has been demonstrated by the number of eminently successful installations to date, but rather in the means of heating and the problem of obtaining a suitable means of indicating the temperature of the plastic itself.

The real problem is to maintain a constant plastics temperature. Fortunately, in calender operation, the

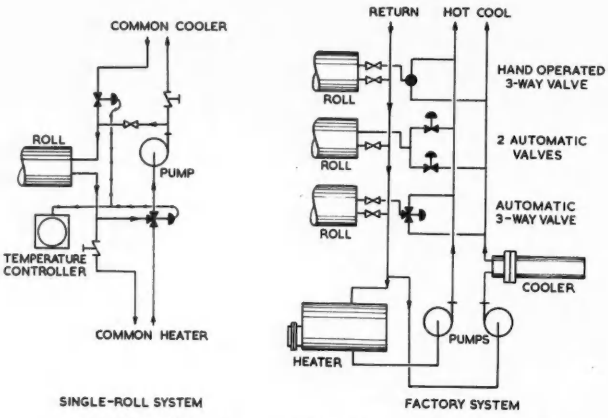

Fig. 2. **Liquid heating and cooling systems for calenders.**

roll surface temperature is close enough to the plastics temperature for control purposes.

EXTRUDERS.

The conventional plastics extruder produces various shapes by forcing the plasticised material through a die. A screw, continuously rotating, takes cold plastic granules or powder from a hopper and plasticises the material by a combination of frictional heating and heat transfer in the cylinder of the machine and forces it out through the die. In Table III, a typical set of temperature conditions for extrusion of polyethylene is shown.

TABLE III. TYPICAL POLYETHYLENE EXTRUSION TEMPERATURES.

	°F
Feed hopper	80
Cylinder:	
Back	300
Middle	400
Front	430
Head	460
Die	480
Screw coolant	115-185
Compound temperature	400-430

In general, carefully controlled cooling is required in the vicinity of the hopper to keep the viscosity high enough for the screw to "grip" the plastic. Then, heating is applied through the cylinder jacket in order to raise the plastic to a suitable temperature for forming. A considerable variation exists in the amount of frictional heat created by different types of plastics at different screw speeds, and also in the temperatures required at different zones of the extruder.

So that the machine may be versatile enough to take care of the requirements of different plastics, it is usually necessary for at least three independent heating zones to be provided, together with a hopper cooling zone and separate die zone, in order that the temperature differential between zones can be adjusted to suit the plastic and the speed at which it is being extruded.

In addition, it is often extremely important to cool the screw. For instance, in the processing of polyethylene, it has been found that the screw temperature is a very sensitive control of the amount of work done by the screw on the plastic, and therefore of the entire operation[4]. To obtain the greatest output from a given extruder, there is an optimum screw temperature for each screw speed.

Some plastics require cylinder temperatures over 600° F. For a plastics machine to handle plastics such as nylons and fluoro-carbons, it is necessary to use a heating medium which can withstand these high operating temperatures. Steam and water cannot be used, owing to the high pressures required. Oils cannot withstand these temperatures without breaking down.

Electrical heating is commonly used, but hot spots and non-uniform heating result and the units are excessively slow in cooling off, resulting in plastic damage and poor production. In addition, since a large amount of frictional heat is often produced in the compound, a direct electrically heated extruder can seldom be applied without producing a pulsating extrusion unless a means for removing the excess heat is furnished.[5] As a result, some plastics extruders are now heated electrically and cooled by means of circulating air, steam, or liquid passing through channels in the extruder cylinder to obtain the desired flexibility, better temperature control, and temperature uniformity.

Proper application of liquid heat carriers can make electrical heating unnecessary, greatly simplifying the heat-control system and making possible the use of economical fuel-fired heaters, rather than costly electrical heat.

Many extruders in current use are heated by hot oil supplied by a constant-temperature source and throttled to each zone by means of hand valves. This system does not permit cooling, nor does it give satisfactory temperature control. Users complain of the time lag required for a valve adjustment to produce a temperature change, and of the non-uniformity of temperature. Such crude systems cannot achieve good results, as they violate several of the principles already mentioned. A circulation and control circuit similar to that shown in Fig. 2 can be used, permitting full control of heating to cooling in each zone, as required.

INJECTION MOULDING.

In the process of injection moulding, the ram of the injection cylinder takes the thermoplastic material from a hopper, pushes it by a reciprocating motion through the cylinder and injects it with a relatively high pressure through a nozzle into a mould. During the time that the plastic mass is being worked down the cylinder, heat must be added to bring the plastic to the proper injection temperature.

One of the limitations placed on the output of an injection-moulding machine is the mass of plastic which can be heated uniformly to the required moulding temperature. Injection-moulding temperatures for styrene and nylon range from 400 to 700° F. Higher temperatures are usually desirable, since they increase the capacity of the machine substantially. There is considerable demand within the industry to make available injection machines which raise larger masses to increasingly higher temperatures. Up to now, electric heating has been used almost exclusively for heating injection-moulding machines because of the insufficient heating area available in older machines.

The Preplasticiser. High-temperature liquids find their application in the injection-moulding process in two places, i.e., for cooling the mould, and for heating the preplasticiser. Preplasticisers are now being incorporated into modern injection-moulding machines in order to make possible the tremendous increase in capacity and the high processing temperatures required to-day.[6]

When a preplasticiser is used, the injection cylinder is not required to heat the material from room temperature to moulding temperature, or to perform the function of producing a homogeneous mass, so that there is no longer any need for the torpedo. Owing to the increased heating capacity of the combined unit, much larger quantities of material can be handled. High-temperature liquids can be applied to the preplasticiser

in much the same way as they are applied to extruders, and offer the same advantages.

The Mould. At one time it was considered satisfactory to cool the mould with cold water. Now, it is generally realised that accurate temperature controls are required, providing not only for cooling but for heating the moulds. Thermal stresses are caused in many of the modern plastics unless the mould temperature can be controlled closely. Since the moulding operation is controlled automatically, it is important that the mould temperature be maintained reasonably constant, in spite of the cyclic nature of the moulding cycle. One of the advantages of liquid heating media for this application is their ability to prevent sudden reductions in the mould temperature, should the machine be stopped.

Numerous moulding difficulties have been traced to wide temperature variations between the mould cavities. These variations are usually the result of circulating the heat transfer medium too slowly and in poorly designed passages.[7]

PLASTICS PRESSES.

Plastics presses, usually hydraulically operated, are used for compression or transfer-moulding thermosetting or thermoplastic materials, as well as for laminating. As distinguished from the plastics operations just discussed, wherein the plastic flows from one temperature zone to another, plastics-press operations usually require that the plastic material remain in place while a series of temperatures is applied in a controlled cycle.

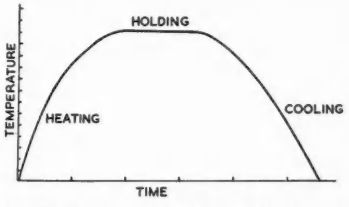

Fig. 3. **Plastics press time-temperature cycle.**

Modern plastics presses are equipped with automatic hydraulic cycling equipment, which can be adjusted to close, dwell, and open in planned cycles, exerting exactly the required pressures on the plastic for the time required to produce the desired results. The time of the cycle depends upon the nature of the operation, the type of plastic, and the temperature of the platen. For this reason it is necessary for the temperature-control equipment to work directly in conjunction with the hydraulic cycle—heating up, maintaining the desired temperature, and cooling on a cycle, such as that illustrated in Fig. 3. Water is most commonly used for temperatures below 400° F. Liquid heating systems for presses and dies are at present under construction with surface temperatures of 800 to 1000° F. These systems can be adapted to plastics processing, should such temperatures be needed.

Many press installations still use steam heat with water injection. This procedure produces tremendous thermal shocks and scaling of the heat-transfer passages,

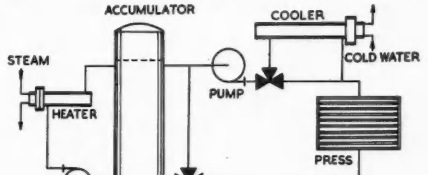

Fig. 4. **Press heating and cooling system with accumulator.**

and for a number of reasons limits the rate and quality of production. More and more of these presses are being converted to liquids.

Liquids make possible the use of heat-accumulator systems to relieve the instantaneous load on the heating plant. Fig. 4 shows a liquid heating and cooling system incorporating an accumulator. It can be seen that this is essentially the same system used for calender heating, except that an additional pump is used to circulate hot liquid between the heater and the accumulator, raising its temperature during the non-heating portion of the press cycle.

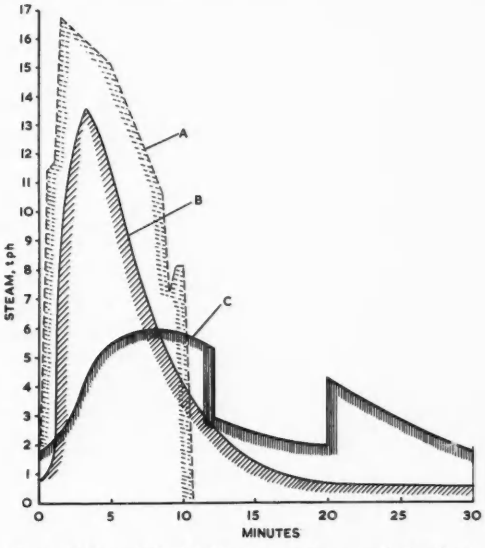

Fig. 5. **Effect of liquid heat accumulator on boiler load.**
(A) Steam consumption with steam applied directly to the platens. (Diagram registered automatically).
(B) Steam consumption for high-temperature hot water heating. (Diagram designed from actual measurement).
(C) Steam consumption for high-temperature water heating, utilising an accumulator of 875 cu ft capacity.

Fig. 5 shows a comparison between the instantaneous steam consumption of a typical platen press and that of the same press heated with water, with and without an accumulator. High-temperature water requires a maximum rate of 13·5 tons of steam per hour, compared with a rate of 17 tons of steam per hour for steam heating. When an accumulator of 875 cu ft capacity is added to the system, the maximum rate of steam consumption is reduced to only 6 tph. The heating plant for the system using an accumulator would need to be only one third the size of that needed for the direct-steam-heated press; or, to put it another way, it would be possible to triple the number of presses served by a given boiler installation by converting from steam to high-temperature liquid and using an accumulator.

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SWEDEN

Mechanism of Combustion Gunpowders and Explosives

By C. H. JOHANSSON. (From *Teknisk Tidskrift*, Vol. 83, No. 34, September 22, 1953, pp. 695-698, 6 illustrations.)

THE following considerations refer to gunpowders of the nitrocellulose type and to secondary explosives, i.e., explosives which burn at a controllable rate without detonation. Their combustion is not an oxidation in the usual sense, but an exothermic decomposition process. At atmospheric pressure, the rate of combustion is of the order of some millimetres per second, or roughly one 10,000,000th of the rate of detonation.

It is remarkable how many theories have been advanced regarding the mechanism of combustion of powders and explosives.[1] According to early theories, developed between 1920 and 1930 in connection with experimental investigations (for instance, by Muraour), it was considered that decomposition and release of energy took place in the solid or liquid phase. Muraour found experimentally that the rate of combustion is approximately proportional to pressure and explained this by stating that the number of collisions of the hot gases is proportional to pressure.

Immediately before the last war, Belaev[2] pointed out that the latent energy of evaporation of most secondary explosives is considerably lower than their activation energy. If the energy of motion of the molecules increases as a result of external supply of heat, they must evaporate before decomposition occurs, so that the exothermic decomposition process must take place in the gaseous phase at the surface of the explosive. Other reasons also indicate that the decomposition does not occur in the condensed phase, and recent theories have been evolved on the basis that the development of the gas phase is decisive for the rate of combustion.

COMBUSTION THEORIES WITH HEAT TRANSFER BY CONDUCTION.

On the basis of a theory for the combustion of gases, developed by Zeldovich and Frank-Kamenetsky, Belaev derived the following expression for the rate of combustion :—

$$v = b\,p^{n/2} \qquad \ldots \qquad \ldots \qquad (1)$$

where p = pressure, b = a constant, and n = order number of the reaction. For a uni-molecular reaction, $n = 1$, and v is proportional to the square root of pressure ; for bi-molecular reactions ($n = 2$), v is proportional to pressure.

This formula is valid for linear combustion, which can be regarded as a steady process in a system of co-ordinates following the combustion zone. The powder or explosive is consumed at the rate at which combustion is propagating. Decomposition is regarded as occurring in a fairly thin layer, in which there is a steep temperature rise up to the final temperature T_m (see Fig. 1). The heat from this layer is transferred by conduction to the condensed phase, the surface of which will therefore be at a pressure corresponding to the boiling point.

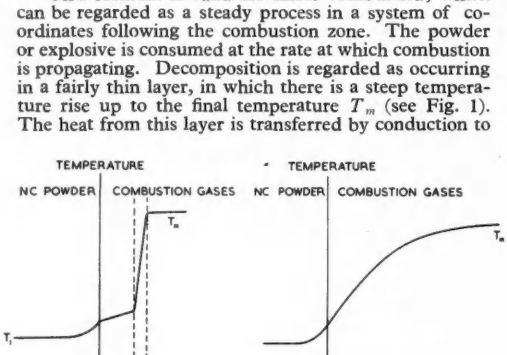

Fig. 1. **Variation in temperature during combustion of nitrocellulose powder according to Belaev (left) and according to Boys and Corner (right).**
T_1 = initial temperature ; T_m = final temperature ; x = distance from surface of powder.

Boys and Corner[3] further developed the theory by taking into account the temperature dependence of the rate of decomposition. The temperature curve thus obtained shows a steady rise with increasing values of px, where p = pressure and x = distance from the powder surface (Fig. 1). This also indicates that high pressures are associated with small values for the thickness of the reactive layer. The rate of combustion increases with pressure approximately in accordance with eq. 1, although the functional relationship is more complicated.

In a recent paper, Corner[4] calculated the diffusion of particles in the reaction layer, but this did not bring about any changes as regards the rate of combustion and its relation to pressure. The preliminary decomposition to a molal weight of the order of 75 is assumed to take place in the condensed phase, so that only a small part of the decomposition energy is liberated. The calculations were made on the assumption that combustion occurs at maximum pressure, as is the case in guns, so that they do not apply to rockets with pressures in the range of ten or twenty atmospheres only.

According to the above theories, the temperature in the reaction zone rises to an equilibrium value determined by the reaction energy, and for powders this is in the neighbourhood of 2000-3000° K. It was noticed, however, by Sänger[5] that there are various indications that combustion temperatures occur which are many times higher than the equilibrium temperature.

In the case of large-size rockets which consume liquid fuel at a rate of 80 to 350 kg/sec, some 20,000 to 100,000 kcal/sec are required for vaporisation and heating to ignition temperature, and, according to Sänger, only a few thousandths of this amount can be effectively supplied by conduction and thermal radiation of gases.

It would appear, furthermore, that the degree of ionisation, in combustion or detonation, is in some cases considerably greater than that corresponding to equilibrium temperature. This conclusion is based on measurements of reflection and absorption of electromagnetic waves of centimetre wavelength in the gas streams discharged by rockets[6] and in detonation wave fronts of explosives[7], as well as on measurements of the deflection of butane/air flames in a powerful electrical field.[8]

EFFECT OF SUDDEN ENERGY DISTRIBUTION ON VARIOUS DEGREES OF FREEDOM OF MOLECULES.

When referring to temperatures which are many times higher than the final temperature, it is necessary to consider the definition of temperature from the point of view of the molecular and kinetic state of the gas. The energy due to thermal motion is distributed among the various degrees of freedom of the molecule, which determine its translational motion, rotation, internal vibrations, excitation, dissociation, and ionisation.

At constant temperature, the molecule is in a state of equilibrium, corresponding to a certain distribution of energy among these degrees of freedom. After a sudden temperature variation, however, the various degrees of freedom do not reach a new state of equilibrium at the same time. This leads to the distinction between translational and rotational temperatures, etc., which denote the temperature which the gas should have for equilibrium with actual values of translational or rotational energy, respectively.

In a sudden adiabatic compression, the quantity of heat released appears first as a translational energy of

motion in the direction of compression. Owing to molecular collisions, the homogeneous velocity rapidly changes into a Maxwellian velocity distribution. Compared with this, it takes considerably longer for the other degrees of freedom to develop, corresponding to rotation, internal vibrations, etc. It was pointed out by Sänger that, if 10 is the assumed number of collisions required to reach translational equilibrium, the corresponding numbers are 10^3 for rotation, 10^5 for internal vibrations, 10^7 for dissociation, and 10^9 for ionisation. The development is shown graphically in Fig. 2, which is valid for combustion conditions in rockets. A large number of collisions must occur before the quantised rotation and internal vibration of the molecule reach a state of equilibrium, since this depends on the probability that the translational energy will be converted into a quantum of rotation, which is fairly small, and the likelihood is even smaller for the conversion into a vibrational quantum. The onset of ionisation is immediate and the power of 10 previously mentioned indicates the number of collisions for ionisation equilibrium after reversion of the translational temperature.

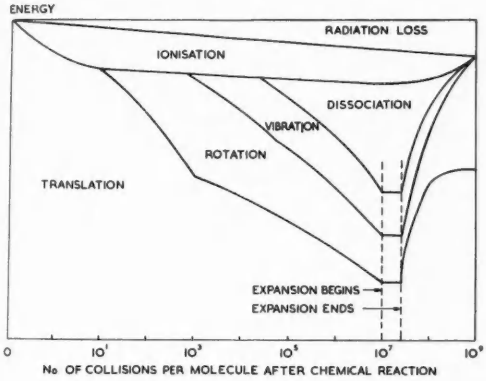

Fig. 2. **Equilibrium conditions in combustion gases of rocket.**

The lag in the development of internal vibrations and dissociation is well known from dispersion and absorption measurements with ultra-sound.[9] It becomes apparent at frequencies in the region of 100 kc, and with rising frequency the contribution of molecular vibration and dissociation to the specific heat tends towards zero. In this frequency range, the ratio of the specific heats γ ($= c_p/c_v$) increases with frequency; hence the velocity of sound also increases, and this results in dispersion and abnormal absorption.

The lag in development of molecular rotation cannot be indicated by ultrasonic means, owing to the high frequency. However, the lag in the decrease of rotational energy can be indicated by means of recordings of band spectra of AlH molecules, which are formed at high temperature and emitted from the cathode in the cooled discharge space with rare gas.[10]

A reason for these time-lags can be found by considering the conditions governing impacts of spherical and non-spherical bodies, as treated in classical mechanics. The kinetic theory of gases developed by Maxwell assumed collisions occurring between smooth, fully elastic bodies of spherical shape. With perfectly spherical bodies, no change in rotational energy can be obtained by collision and the entire energy of motion is distributed among the three translational degrees of freedom. If the bodies are ellipsoidal, equipartition of energy occurs among translational and rotational degrees of freedom. This is so, no matter how small the deviation from the exact spherical shape may be. If the deformation is extremely small, this does not alter the final result, but merely increases the length of time required for it to be reached.

Similar considerations apply to internal vibrations. In this case, each molecule is regarded as consisting of two imperfectly spherical bodies coupled together. Only a small fraction of the energy of motion can be converted into internal vibration as a result of a collision between two such molecules, and the stronger the coupling, the greater will be the time required for the vibrational energy to reach the equilibrium value.

For the excitation and ionisation of the molecule through molecular impacts, the translational energy may also be decisive if the kinetic energy due to thermal motion is concentrated in the translational degrees of freedom, so as to obtain a combined effect, as in a gas at equilibrium at very high temperature. If it is assumed that in an exothermic decomposition process the energy is released as translational energy of the newly-formed molecules, the conditions immediately after decomposition are expressed by

$$T_t = M c_1^2/(3R) = 2W/(3R) \quad .. \quad (2)$$

where M = molal weight, R = gas constant, c_1 = molecule velocity, and W = reaction energy per mole. Eq. (2) gives, for instance, for W = 1500 kcal/kg and M = 27, a temperature T_t of 13,500° K.

Sänger's Combustion Theory.

Sänger[11] calculated luminescent radiation on the assumption that T_t is decisive for the excitation and ionisation of the molecule. Assuming a Maxwellian velocity distribution, it is possible to calculate the fraction ξ of the molecules for which the translational energy is situated between the lower limit corresponding to the beginning of excitation and the higher limit at which ionisation occurs; ξ increases very rapidly with W (see Fig. 3).

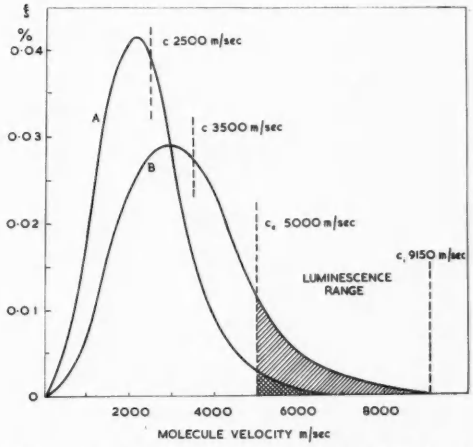

Fig. 3. **Graph showing molecule velocity plotted against ξ.**

In excitation through impact, the kinetic energy of translation of the molecule must be approximately twice as great as the excitation energy. The relation between $h\nu$ (the product of the frequency ν of the emitted light and Planck's constant h) and the velocity c of the molecules with the mass m is obtained as

$$h\nu = m c^2/4 \quad .. \quad .. \quad .. \quad (3)$$

The average life of the molecules, in seconds, can be determined from

$$\tau = 45{,}000\,\lambda^2 \quad .. \quad .. \quad (4)$$

where λ is the wavelength in metres.

To calculate the radiation intensity, it is assumed that the molecule radiates continuously at the wavelength

$$\lambda = (\lambda_e + \lambda_i)/2 \quad .. \quad .. \quad (5)$$

where λ_e and λ_i correspond to the lower limits of molecule velocities c_e and c_i for excitation and ionisation, respectively, according to eq. (3) and using the equation $\lambda \nu = c_o$, where c_o is the velocity of light. The radiation intensity in one direction from a stratum consisting of n individual layers of molecules is

$$I_l = (n h \nu/2 \tau) \times (\xi p N/RT_m)^{2/3} \quad (6)$$

where N is Loschmidt-Avogadro's number.

The radiation energy is consumed in raising the powder temperature, firstly, from the initial value T_1 to a higher surface temperature T_2, and, secondly from this temperature T_2 to the ignition temperature T_3 in the preheating zone between the surface of the powder and the reaction zone. Denoting the corresponding quantities of heat consumed per kilogram of powder by W_{12} and W_{23}, respectively, for these two temperature ranges, this gives the relation

$$I_l = v \rho (W_{12} + W_{23}) \quad .. \quad .. \quad (7)$$

where v = rate of combustion, and ρ = mass-density of powder. Combining eqs. (6) and (7), the final result is

$$v = k n \frac{F(W)}{W_{12} + W_{23}} p^{2/3} \quad .. \quad (8)$$

where k is a constant of known magnitude and $F(W) = (\xi/T)^{2/3}$ is a function of the heat of reaction, which can be calculated.

The thickness of the layer emitting the radiation, expressed as a number of molecular distances n, is unknown and is chosen so that agreement is obtained with observed data. According to eq. (8), the rate of combustion increases proportionally to $p^{2/3}$ (see Fig. 4). Thermal radiation plays a relatively unimportant part. According to Sänger's theory, the temperature conduction is less than the flow velocity, so that thermal conduction is insignificant. The thickness of the preheating layer is approximately ten times greater than the value indicated by the Boys-Corner theory, which assumes that thermal conduction is entirely responsible for heat transmission from the combustion gases to the powder.

It is of interest to consider Sänger's theory applied to a numerical example. With W = 1,000 kcal/kg, ρ = 1,550 kg/m³, W_{12} = 0·25 (473-T_1), W_{23} = 83 kcal/kg, λ_i = 2,050 Angströms, λ_e = 6,880 Angs., $\tau = 9 \times 10^{-9}$ sec, and n = 17, the rate of combustion is

$$v = \frac{0{\cdot}86\, p^{2/3}}{1 - 0{\cdot}0019\, T_1} \quad .. \quad .. \quad (9)$$

where p is expressed in atmospheres and v is in mm/sec.

The relation between the flow velocity w of the gas through the preheating layer, and the critical velocity w_{cr}, is obtained as

$$\frac{w}{w_{cr}} = \frac{v_1 \rho_1}{p} \sqrt{\frac{r R T_m}{M}} \quad .. \quad .. \quad (10)$$

where $r = (\gamma + 1)/2\gamma$. In eq. (10), the ratio w/w_{cr} cannot be greater than unity, and this sets a lower limit for p, below which combustion will not occur.

If there is a sudden decrease in pressure under steady combustion conditions, the radiation intensity falls off immediately, but some time elapses before the surface temperature of the powder and the evaporation adjust themselves to the new equilibrium value. Combustion may then temporarily cease, but, if the surrounding temperature is sufficiently high, it will start again while the gas flow decreases to its new equilibrium value. Furthermore, it should be remembered that combustion cannot take place in narrow pockets preventing adequate development of the preheating layer. Therefore, wide pockets should be provided for low pressures.

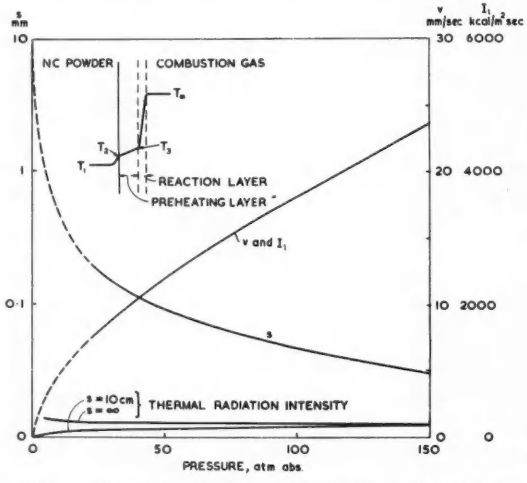

Fig. 4. Rate of combustion of nitrocellulose powder at various pressures, with qualitative variation in temperature along an axis perpendicular to the combustion surface.

Experimental Confirmation of Rate of Combustion Formula.

In order to study the conditions in the transition from combustion to detonation, C. H. Johansson and A. Person, have determined the rate of combustion of a gelatine dynamite at various pressures and temperatures. Although the tests were not carried out to verify various combustion theories, they are, however, of some interest in this connection.

On the basis of Sänger's theory, the rate of combustion of this dynamite can be expressed by the formula

$$v = \frac{A p^b}{1 - t/t_{cr}} \quad .. \quad .. \quad (11)$$

where v = rate of combustion, p = pressure, t = initial temperature, and t_{cr} = critical temperature at which the rate of combustion tends towards infinity. A and b are constants.

According to eq. (11), the reciprocal of the rate of combustion at a constant pressure is a linear function of temperature, for this dynamite. Measured values of $1/v$ plotted against temperature at different pressures gave, in agreement with eq. (11), straight lines which converge towards t_{cr} = 220° C. The initial temperature, however, cannot exceed 130° C, because dynamite then detonates on ignition. If the logarithm is taken of both sides of eq. (11), this gives the relation

$$\log v = \log \frac{A}{1 - t/t_{cr}} + b \log p \quad .. \quad (12)$$

The measured values for log v, plotted against log p, also gave straight lines, as previously. The measurements at room temperature were converted to 20° C. The slope of the parallel lines gave a value of b = 0·86. With t_{cr} = 220° C, the value of A was then determined as A = 0·54.

When these values are substituted in eq. (11), this reduces to

$$v = \frac{0{\cdot}54\, p^{0{\cdot}86}}{1 - t/220} \quad .. \quad .. \quad (13)$$

(*Concluded on page* 36)

Simplification of Joint Design in Power Cables

By N. KLEIN. (From *Revue Générale d'Electricité*, Vol. 62, No. 10, October 1953, pp. 465-475, 8 illustrations.)

IT has been generally assumed that the quality of the insulation in joints is inferior to that of the cable proper, because, during joint making, more cavities, impurities, and soft parts are included in the insulation than during manufacture of the cable proper. For this reason it has been usual to increase considerably the insulation thickness in joints as compared with that in the cable, sometimes by as much as 100%. The thickened insulation has generally been surrounded by an oil bath in a housing, placed in a cast-iron or concrete container filled with a bituminous compound. The diameter of the complete joint has thus been several times larger than that of the cable and the cost of the joint has amounted roughly to 20% of the total cable cost. A reduction in the cost of joints would therefore appear to be desirable, and it would seem that this might be possible, as, in certain circumstances, joints can operate satisfactorily without oil baths.

Systematic investigations were consequently undertaken to ascertain under what conditions oil baths are required in joints and to determine the necessary increase in the thickness of joint insulations, with the object of simplifying joint design.

PHYSICAL PROCESSES IN JOINT MAKING.

A large number of joints was made by jointers of varying skill and the influence of every step of joint making on the insulation quality was observed. It appeared that the insulation quality was mainly determined by the physical processes occurring during the winding-on of the paper tapes and the subsequent treatment of the insulation in an oil bath.

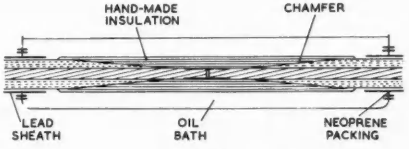

Fig. 1.

Experiments were carried out by making joints on 0·25 sq in., 33-kV single-core cables. As shown in Fig. 1, the insulation was built up to the same thickness as in the cable proper and the joint thus made placed, without a sheath, in a lead trough filled with oil. Power factors of the joint were measured on a Schering bridge after completion, and later at varying intervals over the length between the chamfered ends. The results of these measurements are shown in Fig. 2 for a joint made by a jointer of average skill. Accordingly, the power factor eventually improved value of about 0·0035, which is only slightly higher than that of the cable insulation, and which is almost independent of voltage. Similar behaviour has been observed with most of the other joints, except that the rate of power factor improvement increased with jointing skill. The average time for reaching a quasi-constant value of joint power factor was a week.

It is believed that high power factors after the completion of the joint are due to cavities included in the insulation. The gas in these cavities dissolves slowly in the surrounding oil and the cavities become more and more filled with oil drawn from the bath until they vanish and the power factor of the insulation becomes nearly voltage-independent. This assumption is supported, firstly, by the fact that cavities were found on opening the insulation of joints, whose power factor did not settle down to a nearly voltage-independent value; secondly, by the fact that, when joints were not placed in an oil bath after completion, no power factor improvement, similar to that shown in Fig. 2, could be observed. On the other hand, when joints, which had already reached the stage of voltage-independent power factor, were removed from the oil bath, no further change in their power factor could later be observed.

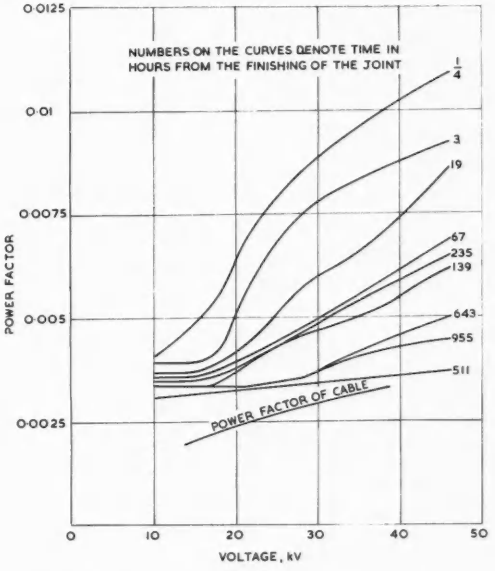

Fig. 2.

Certain joints were subdivided for the purpose of power-factor measurements and it was found that, once the insulation improved to the nearly constant power-factor stage, the power factor was the highest at the middle of the joint, where all the insulation is hand-made. This was to be expected, as hand-made insulation should increase power factors, owing to the added absorption of air, humidity, and other impurities. To measure the magnitude of this increase, lengths of cable with hand-applied insulation were made and improved by oil-bath treatment to the nearly constant power-factor stage.

Measurements at various temperatures show that insulation power factors were on the average 15% higher than those of the impregnated paper tapes from which the insulation was made. As the joint also contains original cable insulation, the increase in its power-factor, compared with that of the cable, is generally smaller.

It has been concluded from these experiments that: (a) Cavities generally vanish from the insulation, when the joint has had sufficiently long treatment in an oil bath; (b) the oil bath can be dispensed with after this treatment; and (c) the power factor of the joint is then slightly higher than that of the cable.

Investigations of the subsequent operations of joint making show that they need not influence the insulation quality. Thus, the application of lead sheaths did not lead to an increase in the power factor, when care was taken not to cause oil losses in the insulation. Furthermore, bending and maltreatment of completed joints did not produce any power factor changes.

Consequently, it appears that the design of joints without oil baths is feasible, the only difficulty being the duration of insulation improvement, during which a

temporary oil bath round the joints seems to be necessary. This problem has been solved by a simple heat treatment :—Joints were made and placed in the lead trough as shown in Fig. 1, but, instead of filling the trough with cold oil, oil at 110° C was used and maintained at this temperature for about one hour. After this period, most cavities disappeared and a nearly voltage-independent power factor resulted. This rapid improvement in the insulation is due (a) to a decrease of the cavity size by temperature and hence faster gas solution, and (b) to the rapid filling of the cavities with oil of greatly decreased viscosity.

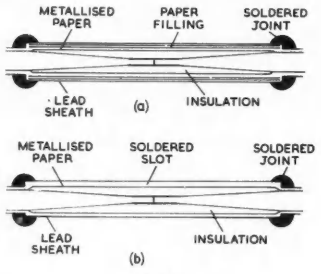

Fig. 3.

As suitable joints are obtained by such a heat treatment and as no oil baths are necessary, the design of joints becomes very simple. Fig. 3 shows two joint designs according to the results obtained. In Fig. 3a, the joint insulation is built up to the outer diameter of the cable sheath ; a lead sleeve is subsequently pulled over the joint and soldered circumferentially to the sheath. In Fig. 3b, the joint insulation is made only slightly thicker than that of the cable. A lead sheath is then formed round the joint, which is circumferentially soldered to the cable. A slot is left open along the top of this sheath and thermal treatment is carried out through this slot. After completion of the treatment, the slot is filled with solder.

Thus, joints can be made in which the diameter is only slightly larger than that of the cable.

INSULATION THICKNESS OF JOINTS.

The quality of the joints described, apart from the power factor, is characterised by the dielectric breakdown strength, which primarily determines the necessary insulation thickness. The breakdown properties of joints were determined by comparison with those of the cable. Short lengths of 0·25 sq in., 33-kV single-core cables were selected for these tests. A joint was inserted in the middle by the methods described above, including heat treatment. The cable ends were provided with wax-filled cardboard tubes, to prevent breakdown over the ends. The test consisted of applying a five-fold nominal voltage, 95 kV, between conductor and sheath, until breakdown occurred. Three groups of tests were made ; in the first, the joint insulation thickness equalled that of the cable ; in the second, the joint insulation was 10% thicker ; and, in the third, 30% thicker. In every group, joints were made by jointers of varying skill, at temperatures ranging from 10 to 30° C and at humidities between 60 and 90%. On the average, breakdown of the test samples occurred after 7 hours. Results of the experiments are tabulated below :—

Insulation thickness	Max. stress in joint kV/cm²	No. of experiments	Breakdown		Comparative state of insulation
			in cable	in joint	
As in the cable	162	8	3	5	Worse in the joint
Cable, plus 10%	146	8	7	1	Somewhat better in the cable
Cable, plus 30%	131	7	7	0	Somewhat better in the joint

Although the table shows the number of breakdowns which occurred in the cable and the joint respectively, it was found that they do not afford a satisfactory comparison of the dielectric strengths of joint and cable. A much better comparison of the respective qualities was obtained by unwinding the insulation of every sample after breakdown and by observing the changes, such as partial breakdowns, carbonisation, waxing, etc. in the insulation. Unfortunately, it is difficult to express these changes quantitatively and the results of the tests therefore appear in the last column of the table as an indication of the comparative state of the insulation after the breakdown tests.

Electrical breakdown in the tests started mainly by discharges in the few small cavities still remaining. It would appear that a 10% increase of the joint insulation thickness makes the joints equivalent to the cable as regards a.c. dielectric breakdown strength in solid-type cables. A condition for this, of course, is that the insulation is improved by the heat treatment described, or by the provision of a suitable oil bath.

An accelerated ageing test was also carried out on joints without an oil bath ; this experiment did not provide any additional information.

JOINTS IN PRESSURE CABLES.

The properties of these joints depend on whether or not there is a gaseous phase present in the insulation. If not, there are no cavities in the insulation and the results of the experiments on the physical processes of joint making are fully valid for joints in this type of cable. It appears accordingly that no oil bath is necessary around the joints of oil-filled, gas compression and similar cables. With respect to increase in insulation thickness, however, conditions are different from those in solid-type cables. An accelerated ageing test was carried out on a length of 0·25 sq in., 66-kV, single-core gas compression cable ; this contained four joints, of which two had the same insulation thickness as that in the cable, and the other two a 10% increase in thickness. The design of these joints is shown in Fig. 4 ; there is no oil bath and hence the outer diameter is only slightly larger than that of the cable. Breakdown occurred in the middle of one of the joints with equal insulation 3 minutes after the voltage was raised to three times the normal value. The corresponding electrical stress at the strand, considered to be a cylinder, was 230 kV/cm².

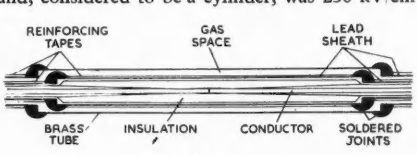

Fig. 4.

Breakdown of these joints usually commences with breakdown of the oil in the tape gaps at the conductor. As the oil absorbs air, moisture, and other impurities during manufacture of the joint, the dielectric strength of the oil decreases and hence the breakdown voltage of the joint is below that of the cable. Owing to experimental conditions, the above breakdown figure is probably below the average ; the average value is still to be determined by tests similar to those carried out on solid-type cables.

No experiments were made on gas pressure cables. As, however, their breakdown properties depend upon the possibilities of discharge in the enclosed cavities, there should be no difference in the dielectric strengths of cable and joint, and equal thickness of insulation should be permissible. This is partly proved by operational experience with joints having only a 20% increase in insulation thickness.

The Behaviour of Thick-Walled Cylinders under very High Pressures

By L. DEFFET and J. GELBGRAS. (From *Revue Universelle des Mines*, 9th Series, Vol. 9, No. 10, October, 1953, pp. 725-740, 15 illustrations.)

Tests, with pressures up to 71,000 psi, show that thick-walled steel cylinders withstand higher internal pressures than those predicted by calculations. The elastic limit and limit of total plasticity correspond approximately to those predicted by known theories.

For the purpose of carrying out tests, the arrangement shown in Fig. 1 was used. A solid bar (3) inserted in the test cylinder (2) serves to diminish the amount of pressure oil required and to pre-compress the sealing glands. Oil pressure is measured by means of a precision Bourdon gauge. An external cylinder (1) surrounds the test cylinder and the space between them is filled with oil at atmospheric pressure. The overall expansion of the test cylinder is thus measured by the displacement of this oil, as indicated by a burette

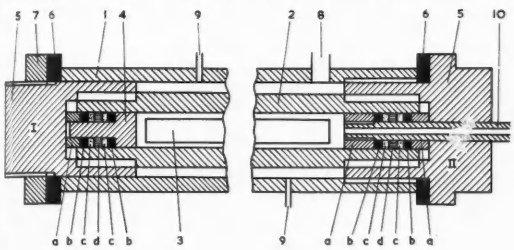

Fig. 1. **Arrangement of test equipment.**

(1) = External cylinder
(2) = Test cylinder
(3) = Solid steel bar
(4) = Steel piston
(5) = Steel flanges
(6) = Rubber packing
(7) = Adjustable steel nut
(8) = Measuring oil inlet
(9) = Connections to burette
(10) = Pressure oil inlet
Sealing glands : (*a*) = steel washer
(*b*) = copper washer
(*c*) = P.V.C. washer
(*d*) = lead washer.

graduated to 100 cc. Many of the test cylinders were also equipped with electric wire resistance strain gauges, so that the elastic limit and limit of total plasticity could be determined with greater accuracy. The threads of the nut (7) were sealed against oil leakage by means of sodium oleate. The length of each test cylinder was 31·5 in. and the following steels were used :—

TABLE I.

Type of Steel	Composition C %	Composition Mn %	Elastic limit f_y tsi	Ultimate tensile strength f_u tsi
Mild	< 0·25	—	16·0	24·4
Medium carbon	0·30 to 0·40	0·45 to 0·90	20·5	38·4

The diameters of the test cylinders and the test results are shown in Table II. P_0 is the pressure at which the elastic limit is reached at the inside of the cylinder, plastic deformation setting in at this pressure; P_1 is the pressure at which the elastic limit is reached at the outside and the tube begins to be plastic throughout; P_2 is the pressure at fracture.

For an internal pressure P in a tube with closed ends, the well-known Lamé equations show that, in the elastic range, the stresses at an arbitrary radius R are:

$$\text{radial stress } f_r = \frac{R_i^2 P}{R_0^2 - R_i^2}\left(1 - \frac{R_0^2}{R^2}\right)$$

$$\text{hoop stress } f_t = \frac{R_i^2 P}{R_0^2 - R_i^2}\left(1 + \frac{R_0^2}{R^2}\right)$$

$$\text{axial stress } f_L = \tfrac{1}{2}(f_r + f_t)$$

The strains follow from Hooke's law. Different criteria have been established as to when the elastic limit is reached. Applied to the problem of a thick-walled cylinder, these criteria state that the pressure P_0 stressing the material to its tensile elastic limit f_y is reached when

(a) $\dfrac{P_0}{f_y} = \dfrac{k^2 - 1}{k^2 + 1}$ (Lamé's criterion of max. principal stress)

(b) $\dfrac{P_0}{f_y} = \dfrac{k^2 - 1}{k^2(1 + n) + (1 - 2n)} = \dfrac{k^2 - 1}{1{\cdot}3\,k^2 + 0{\cdot}4}$

(St.-Venant's criterion of max. principal strain)

(c) $\dfrac{P_0}{f_y} = \dfrac{k^2 - 1}{\sqrt{2(1 + n)\,k^4 + 3(1 - 2n)}} = \dfrac{k^2 - 1}{\sqrt{2{\cdot}6\,k^4 + 1{\cdot}2}}$

(Beltrami's criterion of the total strain energy)

(d) $\dfrac{P_0}{f_y} = \dfrac{1}{\sqrt{3}}\left(1 - \dfrac{1}{k^2}\right)$ (von Mises's criterion of the shear strain energy)

(e) $\dfrac{P_0}{f_y} = \dfrac{1}{2}\left(1 - \dfrac{1}{k^2}\right)$ (Tresca's criterion of max. shear stress).

In these equations, Poisson's ratio n has been taken as 0·3. A comparison of theoretical and experimental values of P_0/f_y is shown in Table III. For mild steel, the experimental values bear out the v. Mises criterion, for medium carbon steel they favour the Tresca criterion. For the thinnest-walled cylinders tested ($k = 1{\cdot}480$), however, both criteria lead to pressures P_0 which are too low, while Beltrami's values are nearest to the experimental values for mild steel, as well as for medium carbon steel.

The condition of equilibrium for a body element of the cylinder, whether in the elastic or the plastic state, is

$$f_t - f_r = R\,d f_r / d R$$

TABLE II.

Outside Dia. R_0 mm	Inside Dia. R_i mm	Ratio $k = R_0/R_i$	No. of tests taken	Mean test pressures, 10^3 psi — Mild steel P_0	Mild steel P_1	Mild steel P_2	Medium C steel P_0	Medium C steel P_1	Medium C steel P_2
37	25	1·480	6	11·7	15·2	21·8	—	—	—
37	25	1·480	6	—	—	—	14·6	20·6	39·7
35	16·5	2·121	4	*	25·5	39·1	—	—	—
26	12	2·167	4	15·1	26·15	47·9	—	—	—
29·3	12	2·440	1	—	—	—	19·2	38·0	>71
37	15	2·467	2	16·4	39·1	>71	—	—	—
37	14	2·643	4	—	—	—	*	43·4	>71
33	12	2·750	2	17·1	41·2	>71	—	—	—
37	12	3·083	1	17·8	45·5	>71	—	—	—
37	12	3·083	3	—	—	—	20·6	50·2	>71

* Values not measured.

TABLE III.

k	Theoretical values, P_0/f_y					Mean exper. values, P_0/f_y	
	Lamé	St.-Venant	Beltrami	v. Mises	Tresca	Mild steel	Med. C steel
1·480	0·373	0·366	0·322	0·314	0·272	0·330	0·317
2·167	0·649	0·568	0·483	0·454	0·393	0·432	——
2·440	0·712	0·609	0·513	0·480	0·416	——	0·418
2·467	0·718	0·612	0·515	0·482	0·418	0·460	——
2·750	0·766	0·641	0·536	0·501	0·434	0·476	——
3·083	0·810	0·667	0·553	0·517	0·447	0·496	0·449

TABLE IV.

k	Theoretical values, P_1/f_y		Mean exper. values, P_1/f_y	
	v. Mises	Tresca	Mild Steel	Med. C steel
1·480	0·45	0·39	0·43	0·45
2·121	0·87	0·75	0·71	——
2·167	0·89	0·77	0·73	——
2·440	1·03	0·89	——	0·83
2·467	1·04	0·90	1·09	——
2·643	1·12	0·97	——	0·94
3·083	1·30	1·13	1·07	1·09

As the condition of plasticity, either the v. Mises or the Tresca criterion may be chosen. According to Tresca's theory, the stress causing plastic flow is the maximum shearing stress, i.e.,

$$\tfrac{1}{2}(f_t - f_r) = \tfrac{1}{2} f_y$$

Combining the last two equations,

$$d f_r = f_y \frac{d R}{R}$$

If this expression is integrated and the constant of integration determined by the boundary condition that $f_r = -P$ for $R = R_i$,

$$f_r = -P + f_y \log_e \frac{R}{R_i}$$

Hence,

$$f_t = -P + f_y \left(1 + \log_e \frac{R}{R_i}\right)$$

and, as before,

$$f_L = \tfrac{1}{2}(f_r + f_t).$$

The strains may be derived from either the total strain law or the incremental strain law. The plastic region spreads from the inside of the cylinder and reaches the outside diameter when

$$f_{ro} = 0 = -P + f_y \log_e \frac{R_o}{R_i}$$

The internal pressure then is

$$P_1 = f_y \log_e k$$

Similarly, from the von Mises hypothesis, it can be deduced that

$$P_1 = f_y \frac{2}{\sqrt{3}} \log_e k \cdot$$

These relations of complete plasticity at constant stress f_y obviously are valid only when the tensile stress-strain diagram of the material shows a fairly long horizontal portion of the yield range so that, at the pressure P_1, work hardening has not yet started at the inside of the cylinder, i.e., they apply only to annealed steels and relatively thin-walled cylinders. If the internal pressure P is plotted as a function of the radial expansion $\Delta R/R$ of the cylinder (Fig. 2), the resulting curve should thus be horizontal at the pressure P_1. This condition is very nearly fulfilled for mild steel cylinders, with $k = 1{\cdot}48$ (Fig. 2a) but certainly does not hold for $k = 2{\cdot}75$ or for medium carbon steel cylinders from $k = 1{\cdot}48$ upwards (Fig. 2b). Comparative theoretical and experimental values are given in Table IV, and show that the v. Mises criterion is appropriate for thin-walled cylinders ($k = 1{\cdot}48$), whereas for thicker cylinders the experimental values confirm Tresca's criterion. The one high value for $k = 2{\cdot}467$ is due to the fact that the less sensitive measurement of overall expansion has here been used. This type of measurement is better adapted to higher values of k where the curves shown in Figs. 2b or 2c result; the plastic limit then reveals itself in a sudden increase of the displaced oil.

For the fracturing pressure P_2, Cook and Robertson[1] have suggested a criterion based on the maximum principal stress, and van Iterson[2] has suggested a limit based on an extension of Tresca's plasticity criterion. In both formulae, the yield stress f_y has been replaced by the ultimate tensile stress f_u. Table V compares the values predicted by these formulae with values found experimentally within the limits, of this investigation ($P_2 < 71{,}000$ psi.).

Both formulae in Table V can be accepted only as empirical rules without rational foundation. Cook and Robertson's rule predicts that the internal pressure can never exceed the ultimate strength of the cylinder material; this is demonstrably untrue for thicker cylinders, where, for instance, $k = 3$. v. Iterson's rule is based on a type of calculation which is valid only until work-hardening commences, and hence is certainly not valid beyond the limit of total plasticity P_1. Nevertheless, present results show that v. Iterson's rule is acceptable for mild steel tubes with small values of k up to about 2·17; its predicted values are too low

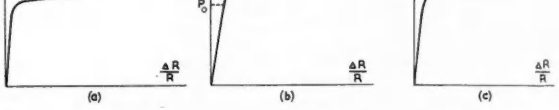

Fig. 2. **Internal pressure P plotted as a function of $\Delta R/R$ of the cylinder.**

Mild steel (k 1·48) Mild steel (k 2·75) Medium C steel (k 1·48) Medium C steel (k 3·1) Stainless steel (k 2·18)

TABLE V.

f_u psi	k	Cook and Robertson $P_2 = f_u \frac{k^2-1}{k^2+1}$ psi	v. Iterson $P_2 = f_u \log_e k$ psi	Experimental results P_2 psi	
54,600 Mild steel	1·480	20,400	21,400	21,900 21,300 22,000	22,000 22,800 22,000
54,900 Mild steel	2·121	34,800	41,200	39,100 40,400	37,400 40,200
54,600 Mild steel	2·167	35,400	42,200	48,300	41,200
54,600 Mild steel	2·467	39,200	49,000	> 71,000	
84,600 Med. C steel	1·480	31,500	33,200	38,400 43,000 38,000	40,400 41,200 37,000

Note.—All fractures ductile, longitudinal, traversing the wall at 45 deg. to the radial direction.

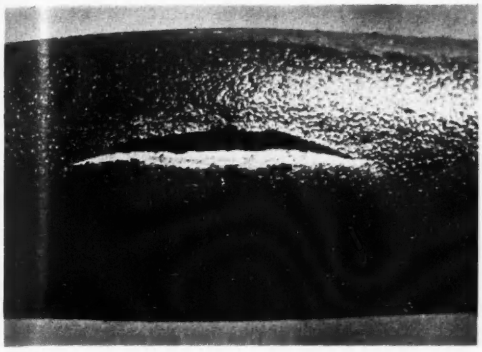

Fig. 3. **Fracture of mild steel tube** ($k = 1{\cdot}48$).

for higher k values and for medium carbon steel in all tests.

Cook and Robertson[1] have obtained, for $k = 1{\cdot}35$ to $1{\cdot}8$, experimental fracturing pressures, P_2 between the values of their own formula and that of v. Iterson. Bridgman[3] and Michels[4] have also carried out tests on thick-walled cylinders. A cylinder of normalised unhardened carbon steel, $f_u = 142{,}000$ psi and $k = 7$, has been fractured by Bridgman at 570,000 psi, whereas v. Iterson's rule predicts a limiting pressure of 277,000 psi. In very hard, not necessarily brittle, steel the fracture is entirely radial; it sometimes starts from the outside but is arrested midway.

A typical fracture in a mild steel tube ($k = 1{\cdot}48$) is shown in Fig. 3. Segments of a similar tube, showing the inclination of fracture at 45 deg. to the radial direction, are illustrated in Fig. 4.

Fig. 4. **Segments of mild steel tube** ($k = 1{\cdot}48$), **showing inclination of fracture at 45 deg. to the radial direction.**

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U.S.A.

Recent Developments in Ignitrons

By G. M. Zins. (From *Electronics*, Vol. 26, No. 12, December 1953, pp. 135-137, 6 illustrations.)

Ignitrons have proved to be of great value in industrial, electrochemical, and railway applications requiring conversion of large quantities of a.c. power to d.c. power at voltages of from 250 V d.c. to 20,000 V d.c. Characterised by an igniter which initiates the arc at the beginning of each desired conduction period, the ignitron offers high efficiency and relative freedom from arc-back.

Ignitron Locomotive.

Because of its inherent ruggedness, high power-handling capability, and high efficiency, the ignitron is well suited for use in locomotives and multiple unit railway cars. The economic advantages of an a.c. trolley system can be combined with the inherent advantages of d.c. traction motors.

Improvements in sealed-type rectifiers have considerably accelerated the acceptance by the railroad industry of ignitrons, of which a cross-section of a typical pumped-up type is shown in Fig. 1. Experience indicates ignitron locomotives have relatively low initial cost, low maintenance, low stand-by losses, high overall efficiency, and low weight.

A typical twin-cab locomotive is rated at 6000 hp or 3000 hp per cab. It operates from an 11 kV, single-phase, 25-cycle trolley system. The essential equipment in each cab consists of:—The main rectifier transformer, which is designed for a single-phase full-wave rectifier circuit; two ignitron cubicles, each containing six sealed ignitrons together with their associated excitation circuits, protective devices, and switching apparatus; a water-to-air type heat exchanger; control circuits; anode reactors; and an a.c. and d.c. filter. Each pair of ignitrons forms a separate cathode circuit, or a total of six separate cathodes, each connected to a 500-hp, series-wound, d.c. traction motor.

The rectifier transformer is provided with tap-changer-under-load equipment to cover the operating range required for accelerating and motoring. Vernier steps between transformer tap positions are obtained by phase control of the ignitrons. This combination of transformer taps and phase control provides 35 different notches for motoring.

Dynamic braking is also obtained. Two of the twelve ignitrons supply exciting current to all six motor fields, which are connected in series for the dynamic braking operation. By varying a series resistor, changing taps on the transformer, and changing phase delay on the ignitrons, fourteen notches of braking are obtained.

The ignitron tubes developed for this application contain a special baffling arrangement and special mounts to eliminate the effects of vibration in service. New firing circuits were required to provide reliable firing over a wide range of trolley voltages with the wave shape of voltage obtained from the main power transformer, which was tapped to provide the necessary auxiliary voltage. One master cooling system was developed to allow one fan to cool the rectifier heat exchanger, power transformer, filter, and anode reactors, together with the other auxiliaries on the locomotive.

The telephone interference problem caused by the rectifier harmonics has been eliminated by a relatively simple and inexpensive a.c. and d.c. filter. Present tests indicate that the filters applied on these first locomotives

may be materially reduced or even eliminated on future models.

ALUMINIUM POT LINE.

The original aluminium pot lines in the U.S.A. were installed using 300-V synchronous converters with pot line capacities in the neighbourhood of 50,000 A. Many of these rotary converters were later rewound for 600-V service to increase station capacity. Initial costs, coupled with high maintenance costs, left this field ripe for the mercury arc rectifier.

During World War II the ignitron completely dominated all other equipment in this field, with typical pot lines consisting of twelve rectifier assemblies of twelve tubes each supplying pot-line loads of 60,000 A at 600 V d.c.

Improved designs of these tubes are now being applied at 72,000 A and 750 V d.c. Recent improvements in protective switchgear for rectifier service are permitting the addition of even more rectifier assemblies on a single pot line, with pot lines up to 120,000 A now being considered at voltages of 750 V d.c. One station now in operation has power requirements in excess of 700,000 kW.

It is customary practice on these large installations to operate two twelve-tube rectifier assemblies from a common rectifier transformer with a quadruple-wye secondary connection and employing anode balance coils. The individual pot lines are now operated multi-phase by employing both delta and wye-connected primaries on the rectifier transformers and auto-transformer-type phase shifters to provide 30 or 36-phase operation per line. Similarly, pairs of pot lines are operated out of phase to give overall operation of 60 or 72-phase operation. With additional units now being contemplated, stations may go up to 108-phase operation. Multi-phase operation of this order of magnitude is required where such large blocks of power are concentrated in one station, to eliminate telephone interference and to improve the wave shape of the line current for the station.

Because of the large number of units in each station, special provision is normally made to degas the entire pot line simultaneously upon installation by supplying reduced voltage to the a.c. bus. Subsequent degassing is usually done on the line, since there is adequate capacity to allow removal of one unit at a time, without overloading the remainder of the rectifiers.

A pot line is usually started by closing all breakers with the igniter short-circuited and then releasing the ignition on all rectifiers simultaneously. This provides reliable pick-up of the pot-line load without unbalance between units.

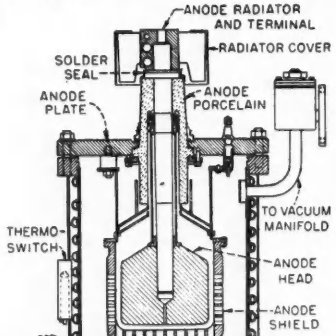


Fig. 1. **Cross-section of typical pumped-up type of ignition.**

This process must be closely controlled. If one unit were to be released in advance of the others, this unit would attempt to carry the entire pot-line load and would then trip on overload. Each succeeding unit could follow and also trip out. Simultaneous release is therefore a feature essential to proper operation.

The anode and cathode breakers provide normal protection against arc-backs and permit the removal of individual units from service. Normal dumping of the pot-line load is best accomplished by tripping the master a.c. breaker which feeds the entire line.

Two of the most notable features of the electrochemical industry are the tremendous concentrations of power and the unvarying 100% load on these pot lines up to one year without shut-down. The rectifier has a well-earned reputation for reliability even on this rugged duty.

HOT-STRIP MILL.

Although many ignitrons have been applied for hot-strip mill service, most of them were used in conjunction with motor-generator sets, the motor-generator sets being used to obtain the variable-voltage feature and the rectifiers being used for full-voltage service and in parallel with these motor-generators. There has been a definite trend, in recent years, towards all-electronic drives for hot-strip mill service.

An all-electronic drive for hot-strip mill service provides many interesting features. A typical hot-strip mill may consist of five or six finishing stands, each stand being driven by an individual compensated d.c. motor. These finishing stand motors range from 2500 to 5000 hp per motor.

In a continuous hot-strip mill, the strip may be in all stands simultaneously for periods up to 40 seconds. It is, therefore, essential that the speed of the individual stands be very closely controlled to prevent pulling or excessive looping of the strip. To control the motor speeds accurately, it is necessary to regulate the rectifier bus voltage to obtain a flat voltage characteristic over the entire load range. To accomplish this, a magnetic-amplifier regulator is used. High speed of response and high sensitivity of the regulator used permit an extremely flat voltage characteristic to be obtained, even with the impact load of the strip entering the rolls.

Another feature required in a drive of this type is the inching operation. A regulated bus voltage of the order of 5 to 10% of rated is required. This feature is used to line up the couplings on the rolls and to calibrate the rolls by test samples.

Reduced voltage for the inching operation is obtained by phase control of the ignition point on the ignitrons. Operation of the rectifier at the high angles of delay necessary increases the probability of arc-backs, with the possibility of forward fires occurring. To minimise these tendencies, a blocking bias is applied to the ignitron grid, driving them negative with respect to the cathode. A pulsing circuit is employed to overcome this negative bias and to drive the grid positive, when the igniter is fired and conduction is desired.

This inching voltage is also regulated as described previously for full-voltage operation. Phase control is provided to allow the mill to be accelerated from inching voltage to full voltage in the prescribed time interval. It is sometimes desired that an idle-run voltage be incorporated into the drive. Approximately 20% of rated voltage is supplied for this operation, the reduced voltage being obtained by phase control. The mill is run at this speed during extended idle periods between strips, to reduce power consumption and to maintain uniform cooling of the rolls. If the mill were shut down completely during such periods, heat distortion might damage the rolls.

Charts and Formulae for Evaporation Processes

By E. KIRSCHBAUM. (From *Z.VDI*, Vol. 15, No. 27, September 21, 1953, pp. 927-932, 8 illustrations.)

THE importance of evaporation processes in engineering is shown by the numerous investigations published on this subject in various countries. A relation between heat transfer and mass transfer was first set up by Lewis[1]. The fundamental aspects were subsequently studied by Schmidt[2] and Nusselt[3], as well as by other investigators. A general view of the conditions can be obtained only by graphical representation. In a further contribution, it was proposed by Mollier[4] that the enthalpy, i.e., the total heat, of the gas could be plotted as a function of the vapour content, in a diagram with oblique co-ordinates. In the following, it will be shown that Mollier's diagram can be modified so as to obtain rectangular co-ordinates, which make it easier to follow the changes of state of a gas flowing over a moist body or liquid. Furthermore, the diagram can be made more complete by including certain temperature curves, termed "t^*-lines," for the states of the gas which correspond to constant temperature values for the moist body, under steady adiabatic flow conditions. The theoretical considerations have been confirmed experimentally and explain why it is erroneous to use the old procedure, which assumes that the change of state of the gas can be determined from a straight-line relation or "mixture line." Finally, the changes of state of the gas are represented by τ-lines, and it will be shown under what physical conditions the t^*-lines and the τ-lines coincide for different gases and materials.

BASIC THEORY.

When air is in contact with a moist body or a liquid, under stationary or steady-flow conditions, the latter medium assumes a temperature which depends on the undisturbed state of the air. This is associated with heat and material transfer processes, which play an important part both in natural phenomena and in engineering applications (e.g., in drying, air-conditioning, and evaporating plants).

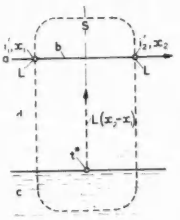


Fig. 1. **Diagram for different states in dry gas and at the surface of a moist body.**

The evolution of the process can be described by considering Fig. 1, which shows a section of an area in which a flow of air is in contact with a moist non-hygroscopic body or liquid. The state of the air is constant at some position S above the moist body. If adiabatic conditions prevail i.e., if no heat is withdrawn from or supplied to the two elements in contact, the moist body or liquid will reach a constant terminal temperature, denoted by t^*.

Assuming that the air is at a higher temperature than the moist body, and that the vapour pressure in the air is lower than at the surface of the body, it is then possible to indicate the quantity of evaporated water by determining the heat balance for the dotted section "d" in Fig. 1. Let L = weight of pure (dry) air passing through the section "d" per hour. The air comes in from the left side with a vapour content x_1 and leaves the section on the right-hand side with a vapour content x_2, which is greater than x_1 owing to the evaporated weight of water received from the dotted section "d." Thus, in this section, $L\,(x_2 - x_1)$ units weight of water are removed per hour from the moist body. If c = specific heat of the water, the decrease in the heat content of the body will be $Lct^*\,(x_2 - x_1)$. For water, the value used in the following for the specific heat will be $c = 1$ kcal/kg-°C. The heat thus absorbed increases the enthalpy, i.e., the total heat content, of the air, so that the heat balance results in the relation

$$Li_1' + L\,(x_2 - x_1)\,ct^* = Li_2' \quad \ldots \quad \ldots \quad (1)$$

where i_1' and i_2' are the relative enthalpy values of the air entering and leaving the section, respectively, based on water at 0° C, following the procedure suggested by Mollier[4].

Eq. (1) is of a type which immediately suggests the use of a diagram to represent the states of the moist gas. Various graphs have been proposed and Mollier considered most suitable a diagram in which the vapour fractions $x_{1,2}$ are plotted as functions of the corresponding enthalpies $i_{1,2}'$. However, as the field covered with rectangular co-ordinates is very small, Mollier introduced oblique co-ordinates, which spread out the values in a more satisfactory manner. This Mollier diagram has not been mentioned in recent literature on process operations ; it is not included, for instance, in the books compiled by Perry[5], Badger-McCabe[6], and Brown[7], and it is also absent from the recent book by Kroll[8] on drying processes, while Grubenmann[9], in the preface to his Diagrams, remarks that many readers found the oblique co-ordinates difficult to apply.

In order to introduce rectangular co-ordinates without reducing the extension of the diagram, the enthalpy of the moist gas can be related to vapour at 0° C, instead of water. This results in some difficulty in expressing the heat balance equation for the gas and the moist body[10]. This difficulty, however, can be completely eliminated by means of the relations

$$i_1' = i_1 + x_1 r_0 \quad \text{and} \quad i_2' = i_2 + x_2 r_0 \quad \text{(2a and 2b)}$$

In these expressions, i_1 and i_2 are the quantities of heat which have to be supplied to a gas and vapour mixture containing one unit weight of dry air, in order to raise its temperature from 0° C to a value t. The corresponding vapour fractions are denoted by x_1 and x_2, r_0 being the heat of vaporisation. The substitution of these relations in eq. (1) gives

$$(i_2 - i_1)/(x_2 - x_1) = \Delta i/\Delta x = ct^* - r_0 \quad \ldots \quad (3)$$

If the distance over which the gas travels is extremely small, $\Delta i/\Delta x$ can be replaced by a differential coefficient di/dx. Thus, for a stable temperature t^* of the moist body, the change of state of the air is fully determined by eq. (3). It is convenient to represent this graphically, by means of a rectangular diagram in which the vapour content x is used for the abscissae, while the ordinates represent the enthalpy i referred to vapour at 0° C.

THE MODIFIED i-x DIAGRAM.

The enthalpy/vapour content diagram fully determines the state of a moist gas. Consequently, it also indicates other related quantities, such as the gas temperature t and the degree of saturation φ. To construct the diagram, it is first necessary to plot the constant-temperature lines.

Let c_L and c_D denote the specific heats of pure air and vapour, respectively. Then the enthalpy is given by

$$i = c_L\,t + x\,c_D\,t \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

This relation indicates that the gas states occurring at constant temperature are straight lines. For the range of temperatures usually considered in evaporation processes, the evaluation can be based on a mean value of the specific heat for water vapour : $c_D = 0{\cdot}46$ kcal/kg-° C,

while the relation for air is : $c_L = 0{\cdot}241 + 0{\cdot}0000155\ t$ kcal/kg-° C, according to ten Bosch[11]. For the saturation curves φ = constant, the evaluation is carried out by means of the relations

$$x = \gamma_D/\gamma_L = 0{\cdot}622 \times \varphi P_t/(P - \varphi P_t) \quad .. \qquad (5)$$

where γ_D and γ_L = specific weights of vapour and air, respectively, φ = degree of saturation (constant for each curve), P = total pressure, and P_t = pressure of saturated vapour at a temperature t. The factor 0·622 is the ratio of the gas constants for air and water vapour.

By putting, for instance, $\varphi = 1$ (saturation line), the points 1 (for 20° C) and 2′ (for 40° C) are obtained. Taking $\varphi = 0{\cdot}3$, with a temperature of 60° C, eq. (5) gives a value $x_{2'}$, which determines point 2. The enthalpy for each of these points is obtained by dropping a perpendicular to the base line (see dotted lines in Fig. 2). Points 1 and 2 can be joined by a straight line " g," which has a slope α corresponding to

$$\tan\alpha = (i_2 - i_1)/(x_2 - x_1) \quad .. \qquad .. \qquad (6)$$

If a parallel to line " g " is drawn through the origin 0_1 of the diagram, it will intersect the perpendicular on the right-hand side of Fig. 2, and the value of the tangent,

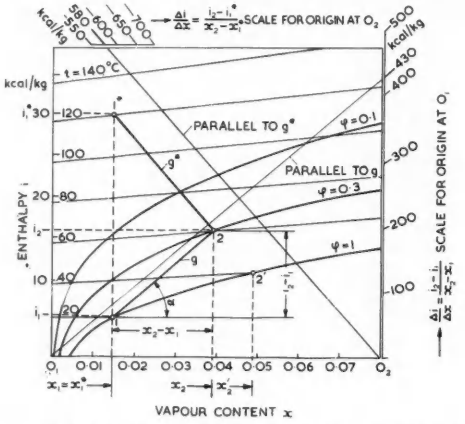


Fig. 2. **Modified and completed Mollier diagram for moist air.**

i.e., $\Delta i/\Delta x$, can be read directly from the corresponding scale. Other slope values are obtained from other pairs of points, corresponding to different initial and final states of the air. Parallels through 0_1 can always be drawn, provided that the tangent is positive. This is the case with hot-air driers, in which the cold fresh air enters under conditions corresponding to point 1, and the outgoing air has the conditions of point 2. If, however, hot air in the initial state of point 1*, for instance, flows over a moist body (as in Fig. 1), its temperature will decrease until it reaches a state such as that represented by point 2 in Fig. 2. The slope $(i_2 - i_1^*)/(x_2 - x_1^*)$ is then negative. A parallel to the line " g " joining the points 1* and 2 can be drawn through a second origin 0_2 on the right-hand side of the diagram. Extended upwards, this parallel will intersect the upper boundary of the diagram, and the negative value of $\Delta i/\Delta x$ can be read off the horizontal scale situated above it. During the change of state from point 1* to point 2, the enthalpy also decreases at the same time as the temperature, but this is so only if the enthalpy i is related to vapour at 0° C, as shown in the above procedure. In a Mollier diagram with oblique co-ordinates, in which the enthalpy is related to water at 0° C, the change of state of the hot air flowing over a moist body is indicated by an increase in enthalpy while the temperature decreases.

The new i-x diagram with rectangular co-ordinates can be further developed, so as to indicate not only the state of the main mass of the moist air (in the following this will be termed the " air point ") but also the state of the air immediately on the surface of the moist body (" surface point "). If the wet body is not hygroscopic, as will be assumed for the time being, then the air is saturated at the surface of the body, and the surface point can be obtained as the intersection of the temperature line for $t = t^*$ with the saturation curve $\varphi = 1$. Eq. (3) indicates that under steady conditions this surface point, which is given by t^* alone, is in accordance with a well-determined relation depending on the state of the air and its change of state. When t^* is given, $\Delta i/\Delta x$ is also determined, and *vice-versa*.

In all evaporation processes, one of the most important requirements is to obtain a definite relation between the state of the air and the moist-body temperature. This requirement can easily be fulfilled with the new diagram, by making use of the ratio α/σ of the heat transfer coefficient and the evaporation coefficient. Here, it will be convenient to define σ, not by a weight concentration per unit volume, but by means of the non-dimensional vapour content (i.e., the weight of vapour per unit weight of dry gas). Instead of having the dimensions of a velocity, the evaporation coefficient has the dimensions of weight per unit area and unit time.

Relations for Heat and Mass Transfer Coefficients.

The heat transfer coefficient α and the evaporation coefficient σ are related to each other by means of Lewis's number[1] :

$$Le = \alpha/\sigma\, c_p \quad .. \qquad .. \qquad (7)$$

where c_p is the specific heat per unit weight of the gas into which the moisture evaporates. Lewis put the above equation equal to unity ($Le = 1$). It is of interest to determine the conditions for which this is true, i.e., where there is a proportionality between the heat transfer and the mass transfer. A first criterion is provided by the non-dimensional Schmidt/Prandtl number ratio :

$$Sc/Pr = (\nu/\beta')\,(a/\nu) = a/\beta' \quad .. \qquad .. \qquad (8)$$

where ν = kinematic viscosity and a = thermal conductivity of the gas, β' = diffusivity of the vapour, Sc = Schmidt's number, and Pr = Prandtl's number.[12] The factor β' is expressed per unit of the concentration gradient, and has, therefore, the same dimensions as ν. As the evaporation coefficient σ is based on the vapour content, use will also be made of a similarly related diffusion coefficient

$$\beta = \beta'\,\gamma_L \quad .. \qquad .. \qquad .. \qquad (9)$$

in which γ_L = specific weight of air ; thus, β has the dimensions of weight per unit time and unit area. It has been shown by Schmidt that a/β' must equal unity when $Le = 1$. The values of Lewis's numbers for the combinations of gas and material occurring in practice can easily be calculated from the corresponding physical constants. If air flows under laminar conditions at a distance s above a moist surface (Fig. 3), the mass of air at the position considered has a vapour content x and a temperature t, whereas at the surface of the material it has a vapour content x_K and a temperature t^*. In the absence of external supply or withdrawal of heat, the quantity of heat transferred through conduction from

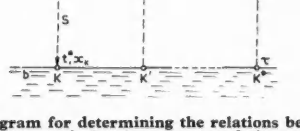


Fig. 3. **Diagram for determining the relations between the state of the gas and the temperature of the moist body.**

the gas to the surface of the material is

$$(\lambda/s)\,(t - t^*) = (\beta/s)\,(x_K - x)\,r \quad .. \quad (10)$$

per unit area and unit time. In eq. (10), λ = thermal conductivity coefficient of the gas and r = heat of vaporisation per unit weight of the liquid. The formula assumes a linear temperature gradient. At the surface of non-hygroscopic bodies, saturated vapour is produced. As this vapour passes through the gas, it becomes superheated as a result of molecular exchanges of gas particles. The heat absorbed by superheating can be 5 to 50 per cent of the heat of evaporation in large drying installations. Using α and σ, instead of eq. (10),

$$\alpha\,(t - t^*) = \sigma\,(x_K - x)\,r \quad .. \quad (11)$$

and this, in conjunction with eq. (10), gives the relation

$$\alpha/\sigma = \lambda/\beta \; .. \quad .. \quad .. \quad (12)$$

which is valid for laminar flow. Although eq. (12) has been derived for the evaporation process only, the same expression has been obtained by Hausen[13] for the reverse case of vapours extracted from gas by cooling processes, using a different derivation.

For turbulent flow, use can be made of Nusselt's similarity considerations[3], which give the heat transfer relation

$$\alpha\,d/\lambda = C\,(w\,d/\nu)^m \times (\nu/a)^n \quad .. \quad (13)$$

as well as the following expression for mass transfer :—

$$\sigma d/\beta = C\,(w\,d/\nu)^m \times (\nu/\beta')^n \quad .. \quad (14)$$

In the case of a flow of gas through a tube, d represents the tube diameter, and the constant C includes the ratio of tube diameter to tube length. The gas flow velocity is denoted by w, and m and n are constants. The validity of eq. (14) has been confirmed by Kirschbaum, Kienzle, and other investigators. By dividing eq. (13) by (14), and using $n = 1/3$ and $a = \lambda/\gamma_L\,c_p$, the following important result is obtained for turbulent flow :

$$\alpha/\sigma = c_p^{\frac{1}{3}}\,(\lambda/\beta)^{\frac{2}{3}} \quad .. \quad .. \quad (15)$$

It should be noted that if the ratios $Sc/Pr = a/\beta' = \lambda/\beta\,c_p$ are made equal to unity, then equations (12) and (15), which have been derived for laminar and turbulent flow, both give Lewis's formula in its original form :

$$\alpha/\sigma = c_p \quad .. \quad .. \quad .. \quad (16)$$

With the aid of the latest numerical data for λ and β[11, 15, 16], it is possible to calculate the values of α/σ and Lewis's number for various combinations of gases and liquids. The following table gives a comparison of calculated values with the experimental results determined by various investigators (mean values being indicated in all cases) :—

		Air and water vapour		Air and ethanol vapour	
		calculated*	measured[14, 15, 19]	calculated†	measured[14, 16, 17]
Laminar flow	α/σ	0·1976	α/σ = 0·20–0·23 and Le = 0·84–0·95	0·557	α/σ = 0·51 and Le = 2·1
	Lewis's No.	0·82		2·31	
Turbulent flow	α/σ	0·2115		0·421	
	Lewis's No.	0·88		1·75	

α/σ is in kcal/kg–°C; * = mean values between 0 and 100° C; † = at 0° C.

There is thus fairly good agreement between calculated and measured results. The small differences are due partly to inevitable measuring errors and partly to uncertainties in the basic data used for the calculation of Le and α/σ. It therefore appears possible to determine these quantities from the material parameters, particularly α/σ, which is not greatly affected by temperature.

In tests of a cooling apparatus, Merkel[20] obtained Lewis's numbers considerably different from unity. He explains this by stating that the temperature of the water surface was lower than the measured mean temperature of the water. If a linear relation between air temperature and vapour content is assumed[20], this does not lead to the conclusion that the water temperature is constant and equal to the terminal temperature along the entire path of the air flow. From the linear relation between t and x, the mathematical result would be that the vapour content at the surface of the water, at a point where the gas flow temperature is t, is also linearly related to water temperature. This invalidates, therefore, the assumption used for concluding that Le is always equal to unity.

Relations Between State of Gas and Transfer Coefficients.

Although the ratio α/σ of the transfer coefficients can be evaluated by means of material parameters, it also determines the state of the dry gas under stable adiabatic conditions, if the temperature t^* of the moist non-hygroscopic body is given, and *vice-versa*. The temperature t^* corresponds to a saturated vapour content x_K (see Fig. 3), and this, in turn, determines the " surface point " x_K in Fig. 4.

The question is, now, if x_K and t^* are the values at a surface point K of the liquid, what are the values x and t of the corresponding air point K_L situated above it? The answer is provided by eq. (11), which gives the ratio

$$\alpha/\sigma = r\,(x_K - x)/(t - t^*) \quad .. \quad (17)$$

for which the numerical values can be regarded as known. Assuming any value for the air temperature t, the " air point " K, representing the state of the air, must be situated on the corresponding t-line (see Fig. 4).

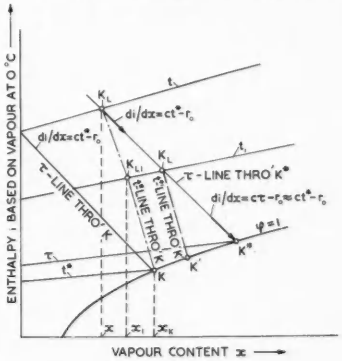


Fig. 4. **Determination of line representing state of air for a steady temperature of the moist body and of line of equal cooling limit.**

The required value of the vapour content can be calculated from eq. (17), which gives

$$x = x_K - (\alpha/\sigma)\,(t - t^*)/r \; .. \quad (18)$$

All the values on the right-hand side of eq. (18) are known. The perpendicular through x on the base-line gives on the t-line the point of air equilibrium K_L. In the same way, another air temperature t_1 will serve to determine on line t_1 an additional point of air equilibrium K_{L1}. Joining together all the points thus found, the t^*-line between K_L and K (indicated as a chain-dotted line in Fig. 4) is obtained. The t^*-line is the locus of all the points of air equilibrium corresponding to the surface point with the temperature t.

The t^*-lines thus give corresponding states of equilibrium but will not indicate how the state of the air varies. This information is obtainable from eq. (3). The surface point K with the temperature t^* is related to a point of air equilibrium K_L by means of Fig. 4. From the scale on the outer boundary (see Fig. 2), for the

numerical value of $ct^* - r_o$, the slope of the straight line can be found directly, and a parallel to this line is drawn through the point K_L in Fig. 4. The variation of the state of the air is characterised by this line and by the arrow pointing outwards from point K_L. The line with the arrow intersects the t_1-line at the point K_L'. At the end of an air path of theoretically infinite length (Fig. 3), the wet body and the air reach the same temperature τ. This is found by extending the τ-line passing through K until it intersects the saturation curve $\varphi = 1$, which gives the surface point K^* with the temperature $t^* = \tau$. The temperature τ is the actual cooling limit. Strictly speaking, at the point K^* the value of di/dx is somewhat different from that at K_L. However, the difference between ct^* and $c\tau$ is extremely small, in comparison with $r_0 = 597$ kcal/kg, and for practical purposes sufficient accuracy is obtained by putting $ct^* - r_0 = c\tau - r_0$. The variation of the state of the air is thus indicated by these τ-lines.

The indications given above can also serve to construct τ-lines as curved paths, where increased accuracy is desirable. For such cases, a straight line through K^* is drawn with a slope $di/dx = c\tau - r_0$ up to the next temperature line, for instance, t_1 in Fig. 4. This gives the point K_1', through which another line with the slope $di/dx = ct^{*'} - r_0$ is drawn ($t^{*'}$ being the temperature of equilibrium at the surface point K'). This second line is valid up to another temperature line at a still higher level, etc. Finally, the broken line is replaced by a smooth curve.

The t^*-lines and the τ-lines for the same temperature value intersect each other at a point which is situated on the saturation curve $\varphi = 1$. If the wet body is hygroscopic, then the air on its surface is no longer saturated. The degree of saturation φ is related to the water content of the liquid by means of curves known as "absorption isothermals." In the i-x diagram, the "surface point" (which indicates the state of the air at the surface of the body) is in this case situated at the intersection of the temperature line of the wet body with the curve for the corresponding degree of saturation. For these surface points, the t^*-lines and τ-lines have the same significance as previously. They also intersect each other for a certain temperature value at a point which is now situated on the curve for the degree of saturation corresponding to the water content at the surface of the hygroscopic body[9, 10].

(To be concluded)

HOLLAND

The Determination of Droplet Size in Arc Welding by High-speed Cinematography

By P. C. VAN DER WILLIGEN and L. F. DEFIZE. (From *Philips Technical Review*, Vol. 15, No. 4, October 1953, pp. 122-128, 9 illustrations.)

To provide data regarding droplet size in arc welding, films have been made of the transfer of weld metal, using a camera taking up to 3000 *frames per second. With the same camera, colour films have also been made, presenting a very clear picture of the welding process as a whole.*

INVESTIGATION into the manner in which metal is transferred from the welding electrode to the work in arc welding has revealed that this usually takes place in the form of free droplets of molten metal. Sometimes, the droplets are so large that they constitute a short circuit while flowing from the electrode into the pool, and in this case the droplets can no longer be considered to be wholly free.

To a great extent, droplet size determines the welding characteristics of the electrode; it is known that small droplets result in a smooth bead, and that the smaller the droplet, the more stable the arc. This stability relationship is especially noticeable in a.c. welding, where the arc is established twice per cycle. Electrodes producing small droplets, moreover, melt more quickly than those which give the larger drops, because a large drop usually clings to the electrode for a relatively longer time, thus impeding the melting of fresh weld metal. On the other hand, the welder will generally prefer to employ an electrode giving a large drop when it is required to span the gap between two plates.

The number of different kinds of electrode manufactured has increased in the course of time, and the need has arisen for a quantitative determination of the droplet size occurring with the various electrodes. In order to meet this need, systematic measurements have been carried out in the Philips laboratories at Eindhoven. In order to determine the size of the droplets, films were made of the arc, a method often employed to demonstrate the transfer of the weld metal from the electrode to the work. It was already known that the processes taking place within the arc are so rapid that very high film speeds (> 1500 frames per second) would be required to permit these processes to be followed. Use was made of an Eastman high-speed camera, capable of taking a maximum of 3000 frames per second on 16 mm film; exhibited at a speed of 24 frames per second, the pictures are seen slowed down by a factor of up to 125. The camera does not, of course, operate at full speed from the moment of starting; this speed is developed gradually, approximately 1000 frames per second being attained after 2 m of film have passed through the camera, 2500 frames per second after 10 m, and 3000 frames per second after 30 m.

To obtain an indication of the speed relating to every part of the film, 50-cycle a.c. was used for the welding arc; the current thus passes through zero 100 times per second, so that the arc extinguishes that number of times per second. Another argument in favour of filming an a.c. arc is the increasing use of a.c. welding technique, which involves much less difficulty due to magnetic arc blow and requires less expenditure on equipment.

Fumes, as well as the light emitted by the arc, tend to make filming difficult. Fumes can be blown from the field of view by means of a current of air directed across the arc. To minimise the effect of excessive light from the arc itself, a powerful light source was placed behind it, as shown in Fig. 1. Originally, a 60-A arc lamp (A) from a cinema projector was used, the light being concentrated around the welding arc (B) by a concave mirror, to produce a background of high and constant brightness. The welding arc thus became almost

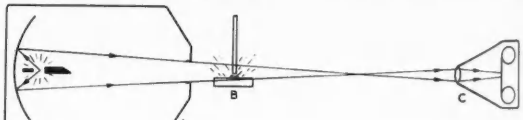


Fig. 1. **Layout for filming weld metal droplets in the welding arc in silhouette.**

invisible against the background, and the droplets could be filmed by the camera (C) in silhouette.

However, this light source was cumbersome and proved rather unmanageable in use, and it was subsequently replaced by a water-cooled mercury vapour lamp, this being much more convenient to handle. To concentrate the light, a lens was mounted between the lamp and the arc. Another advantage of this type of light source is that it introduces no interfering objects in the beam ; the carbon arc and mirror had to be very carefully watched, to ensure that no shadow from the carbon-holder fell across the welding arc.

In the actual apparatus used in conjunction with the mercury vapour lamp, the welding electrode was mounted in such a way that the arc remained in the same place while the electrode was being consumed, with the electrode-holder lying in the direction of the electrode itself and supported by four guide rollers. The work was pulled along below the arc at the required speed by an electric motor. It was not found necessary to use automatic feed for the electrode-holder to maintain a constant arc length. The arc length was checked by means of an optical system with a calibrated eyepiece, and the camera was started as soon as the arc attained the desired length. The operator had no difficulty in keeping the arc length constant for the few seconds needed to take the shot (15 m of film).

Determination of Characteristic Droplet Size.

The individual pictures on the film are projected one by one on the screen, from which the diameters of the droplets, as well as the diameter of the electrode, are measured. As the actual electrode size is known, the real diameter of the droplets is easily ascertainable.

It is first necessary, however, to define the size of the droplet to be regarded as *characteristic* of an electrode. The transfer of metal is determined by the *volume* of the droplets, so that it is desirable to work in terms of droplet volumes, as obtained from the observed diameters. Let n_i be the number of droplets found, of which the volume is v_i. It will be clear that the arithmetic mean droplet volume $\Sigma n_i v_i / \Sigma n_i$ will not be suitable for representing the volume of the characteristic droplet. As against the very large number of small droplets, the influence of the larger drops, which, after all, are those contributing most towards the transfer of metal, would thus remain obscured. This objection is removed by counting each drop a number of times proportional to its volume, i.e., to the contribution of the droplet to the transfer of weld metal. The characteristic droplet volume is then defined as :

$$v_c = \Sigma n_i v_i^2 / \Sigma n_i v_i$$

Each droplet is encased in a protective coating of slag, and the volumetric percentage of slag will certainly vary between one droplet and another. However, in order to take the average volume of slag into account in the calculation, the characteristic droplet volume is reduced by the (known) volumetric percentage of slag in the molten bead, taking the result to be the characteristic volume of the iron core of the droplets. From this, the *characteristic diameter* d_c of the droplet core is then obtained.

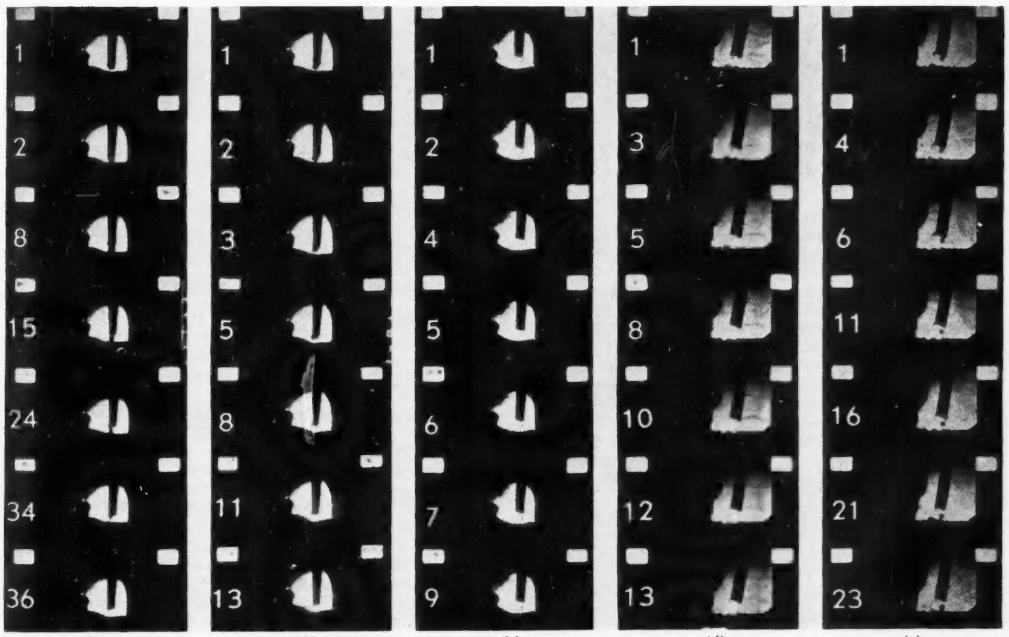


Fig. 2. **Silhouette pictures of droplet transfer in arc welding. Some of the intermediate frames have been omitted from each strip, as will be seen from the numbering.**

(a) Metal transfer from Philips 48-5 gas-shielded electrode. The short-circuiting of the arc is clearly visible, starting at the moment the alternating current passes through zero and lasting almost one whole cycle ($^1/_{50}$ sec). Film speed, 2000 frames per sec.
(b) Additional pictures of the Philips 48-5 electrode. In frames 1, 2, and 3, the arc is extinguished (current = zero). In 2 there is a momentary short circuit, but no material is transferred. From 5, 8, 11, and 13 it will be seen that the arc exerts a force on the droplet, thus distorting it.
(c) With the contact electrode C18-4, which is derived from the Philips 48 electrode, the metal transfer is in the form of small droplets. Weld made with free arc.
(d) The low-hydrogen (basic) electrode, Philips 56-5. Two free droplets are seen, the upper one of which has the dimensions of the characteristic droplet ($d_c/D = 0.57$). The arc is extinguished only in frame 3.
(e) Additional pictures of the Philips 56-5 electrode. Here, a large droplet is seen in process of being transferred. The arc is extinguished in 1 and 23. The 23 frames represent one half-cycle of the a.c. (1/100 sec).

A complication is encountered with contact electrodes in that the size of the droplet cannot be determined from the silhouette, if the weld is made in accordance with usual practice. Normally, the cup of the electrode rests on the work, and the space between the coating and the work is then so small that the formation of the droplets cannot be observed. To enable the droplet size to be determined, welding with the contact electrode was therefore effected with an open arc. It remains a moot point whether the size of the characteristic droplet in normal contact welding procedure would be the same.

The values obtained for contact electrodes C18-4* and C20-4, as well as for the oxide-silicate electrode Philips 50-5 (from which contact electrode C20 was derived), are shown in Table I. A few of the results of measurement on the basic (low hydrogen) electrode Philips 56-5 are also included.

TABLE I. DIAMETER OF THE IRON CORE OF THE CHARACTERISTIC DROPLET FOR SEVERAL TYPES OF WELDING ELECTRODES.

Electrode*	Current (A)	Arc voltage (V)	Arc length (mm)	Drops per sec.	d_c (mm)	d_c/D	d_c/D' (for contact electrodes)
C 18-4	180	45	4·8	185	1·9	0·47	0·41
,,	180	47	6·6	133	2·0	0·50	0·44
,,	165	42	6·1	145	1·8	0·44	0·38
C 20-4	190	35	6·1	91	2·3	0·58	0·44
Philips 50-5	200	35	4·8	162	1·3	0·26	—
Philips 56-5	230	37	8·0	29	2·7	0·54	—
,,	230	37	6·2	32	2·8	0·56	—
,,	230	38	5·3	42	3·3	0·66	—
,,	200	38	5·5	24	2·6	0·53	—

In general, larger droplets are to be expected to result from larger core diameters D, so that, to characterise the type of welding rod, the value of d_c obtained should be divided by the value of D. For the contact electrode, moreover, the ratio d_c/D' is also given, where D' is the core diameter which the contact electrode would have if all the iron in the coating were included in the core. (In the C18 electrode, 24% of the iron is in the coating as powder; in the C 20, 41%).

DISCUSSION OF RESULTS.

The gas-shielded electrode Philips 48 was specially designed to give a large droplet, and the film in fact showed that metal was transferred from this electrode only when the arc was short-circuited (Figs. 2a and 2b). It is therefore somewhat surprising that with the C18-electrode, which is the contact version of the Philips 48, the material is transferred only in the form of small, free droplets (Fig. 2c). The conversion to contact electrode has thus resulted in an appreciable decrease in the size of the droplet. Just the opposite has taken place, however, in the oxide-silicate electrode Philips 50 and its contact counterpart, the C 20; the table shows that the ratio d_c/D' of the C20 is almost twice the ratio d_c/D of the Philips 50. No explanation has as yet been found for these facts.

The ratios d_c/D' of the C18 and C20 electrodes are practically the same. It is remarkable that a much larger percentage of very small droplets was found for the C18 than for any other of the electrodes measured. In the calculation of d_{c3} however, these smaller droplets are of minor importance.

The molten metal at the extremity of the Philips 50 electrode, as well as that in the metal pool, is very mobile. This fact, coupled with the smallness of the droplet (the smallest measured) is related to the comparatively high FeO content of the molten metal (approx. 0·04%), which greatly reduces the viscosity and surface tension of the molten metal. The droplets transferred are irregular in shape.

The Philips 56, low-hydrogen electrode gives the largest droplets (Figs. 2d and 2e); the spherical form of the droplet is characteristic of this electrode. It is known that the FeO content of the weld metal of this basic electrode is very low (0·001%); the viscosity and surface tension are accordingly high.

THE "OPTICAL EFFICIENCY."

In order to gain some impression as to whether the transfer of weld metal was actually recorded quantitatively on the film, the volume of material (iron and slag) transferred per second was first determined from the measured droplet diameters. This result was then divided by the volume of iron and slag per second, ascertained from the actual weight of the quantities of material deposited and the known specific gravities. For the C18-4 electrode, this "optical efficiency" was found to be 100%, as, of course, it should be. The basic electrodes gave values of 150 to 200%, and the Philips 50 electrode only 50%. By moulding the droplets from the basic electrodes in a synthetic resin and then cutting them through, it was shown that many of these droplets contained cavities. Hence, the droplet volumes observed from the film were greater than their true volumes. (In normal welding, the droplets merge in the liquid pool and the cavities entirely disappear).

In the case of the Philips 50 electrode, several droplets were apparently not observed; these were presumably quantities of very small droplets which had been rendered invisible by smoke, or by the fact that their silhouettes were indistinguishable from blemishes in the film. Clearly, in this case, the value of d_c obtained for this electrode, which is already very low, is nevertheless too high.

COLOUR FILMS.

In addition to black-and-white silhouette films, some colour films were also made with the intention of giving an overall picture of the welding process. The light source (A) was mounted so as to illuminate the work at slightly more than grazing incidence, as indicated in Fig. 3. The camera (C) was similarly mounted, so as to photograph the work (B) from an angle. In order to get as much reflected light as possible into the camera, the surface of the work was polished before each shot; in spite of this, so much light was lost that the arc was much brighter than the background.

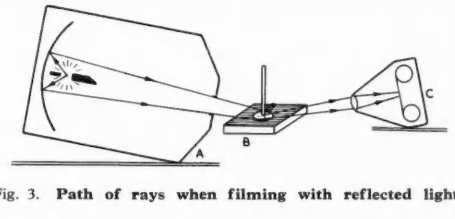


Fig. 3. **Path of rays when filming with reflected light.**

The advantage of filming from an angle is that the pool of metal under the arc, with the layer of liquid slag on its surface, is then clearly visible. This gives a good perspective view of the welding processes. In addition to the advantage of more or less natural colouring, the use of colour film, owing to its laminated structure, gives pictures almost entirely free from the halation which otherwise occurs when the camera is directed towards the light source.

These films demonstrate the steadier arc and smaller spatter losses obtained when the contact electrode is used; they also show the shape of the arc. Filming with the contact electrode at an oblique angle, giving a view into the cup, confirms that the end of the core metal is always covered with a layer of slag during welding.

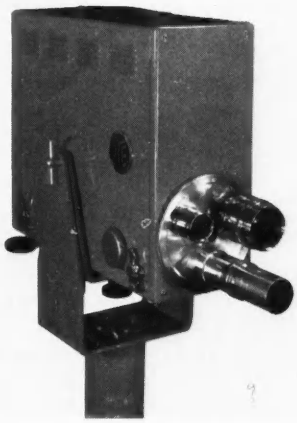
*The second figure in the designation of all electrodes mentioned indicates the core diameter in mm.

New Materials, Processes and Equipment

INDUSTRIAL TELEVISION EQUIPMENT

The latest product of the research organisation of Pye Limited, of Cambridge, is an economical, high-definition television system for use in science and industry.

The entire equipment for the generation and control of the television image, consisting of camera, pulse generator, and power supply components, is contained within a compact camera case measuring only 16¾ × 6⅛ × 14 in. A specially designed Pye high-definition 14-in. picture monitor, connected to the camera *via* a single coaxial cable, completes a television chain capable of conveying immediate and accurate visual information of any kind to observers, who may be located at distances up to 1000 ft from the camera.



The new industrial camera employs a Cathodeon Staticon miniature TV camera tube, measuring only 6 in. in length by 1 in. in diameter. This tube operates on the " photo-conductive " principle, as distinct from the " photo-emissive " principle used in tubes in conventional television cameras. As a result, a basically simple type of construction can be employed. In this connection, it may be mentioned that considerable research has been undertaken to simplify the complex circuitry normally associated with TV transmission equipment. The measure of success attained can be gauged from the fact that only 23 valves are used and that this comparatively small number carries out the functions of camera tube scanning, video amplification, accurate pulse generation to a standard usually employed only by professional TV stations, and, finally, provides an amplitude-modulated radio-frequency output signal for application to the aerial socket of a conventional television receiver, should it be desired to use one.

Unusual mechanical design is also a prominent feature of the equipment. All components are located on a single chassis unit, mounted vertically between the front and rear panels of the camera. In addition, this chassis constitutes the mechanical framework and has been constructed to impart more than adequate strength to the complete assembly. The camera tube is located near the base of the unit, mounted inside the deflection, focusing, and alignment coil assembly controlling the scanning process of the electron beam generated within the tube. Critical optical focusing is achieved by moving the pick-up tube and coil assembly backwards and forwards with respect to the operating lens; a special carriage for this purpose is operated by a rack and pinion system *via* a twin-speed epicyclic gear, controlled by dual focusing knobs on the right-hand side of the camera case, for coarse and fine adjustment.

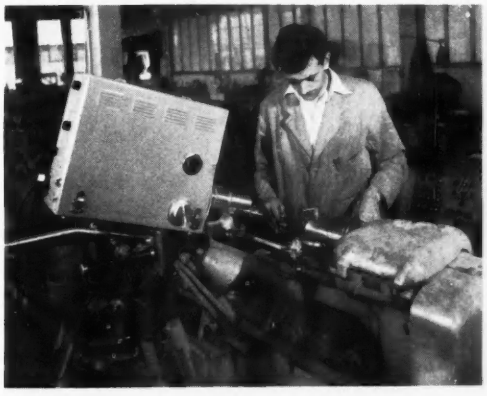
The power supply components are accommodated in the lower portion of the chassis, while the video amplifying, scanning, and pulse generating circuits occupy the larger, upper section. A silent and efficient ventilation fan is mounted between these sections, creating a continuous flow of air and maintaining cool working conditions for all components.

The camera operates on all a.c. supplies from 90 to 240 V, 50-60 cps, power consumption being only 150 W approximately. The rotary lens turret accommodates three precision coated objectives, giving a wide choice of viewing angles. The four lenses currently available are of 1 in. focal length (f:1·4); 2 in. (f:2·3); 4 in. (f:3·5); and 6 in. (f:5·6), respectively. The camera, which is supplied complete with a lightweight carrying case, weighs only 31 lb, without lenses, and is available in two models, *viz.*:—British and International, for 405-line and 525/625-line systems, respectively.

Additional features of the new camera include low pick-up tube replacement, costs; simple maintenance, the outer case being easily removable, exposing all components and wiring; and extremely simple operation, accomplished by only four external controls and a power on-off switch, permitting satisfactory operation by any layman.

The 14 in. high-definition picture monitor supplied with the equipment is a precision instrument, with a power consumption of only 200W, and is designed to give the highest possible picture quality. A " dark-screen " viewing filter is fitted, thereby ensuring bright, clear pictures under all ambient lighting conditions. If desired, a mobile cradle mounting for the monitor can be supplied as an accessory. As in the case of the camera, two models are available, British and International, respectively. A 27-in. monitor is also available and, as indicated previously, any domestic type of television receiver can be used alternatively, if desired. Furthermore, virtually any number of receivers can be operated simultaneously from the same camera.

The uses to which equipment of this type can be put are almost unlimited. In the United States, industrial



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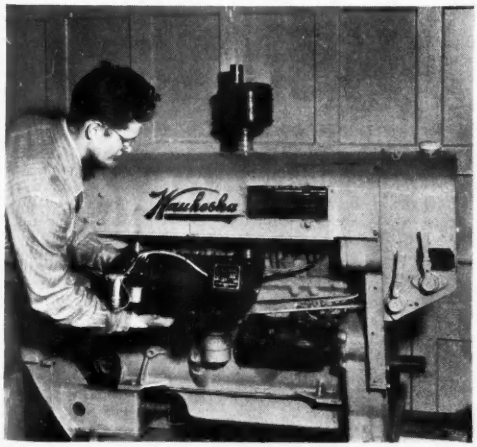
television has already found a wide range of applications, particularly in the heavier industries, in cases where work cannot be watched by the human eye, as, for example, in blast furnaces, or where close observation may be dangerous, as in certain experimental work on explosives. Pye equipment of the type described is employed in Great Britain in similar applications and in others, notably in connection with banking institutions where it is required to relay information, clients' signatures, etc., between provincial premises and headquarters. Underwater television, of great value in salvage operations, is already an accomplished fact, as, too, is the use of television in hospitals and in education. Thus, for instance, the recently opened College of Rubber Technology at Holloway has paved the way by installing this type of equipment for teaching purposes. The new College has been completely wired for television in every lecture room, and, in a demonstration during the opening ceremonies, a Pye camera was installed in the rubber shop, pictures being viewed in the lecture theatre on a 27-in. monitor by an audience of 180. A typical use of this kind, showing one of these cameras set up for televising a lathe operation, is illustrated.

ENGINE PRE-HEATING EQUIPMENT

A new engine preheating equipment, which makes it possible to start diesel or petrol engines quickly under severe arctic conditions, has been developed by the Stewart-Warner Corporation, of Chicago, U.S.A.

The new equipment, known as the " South Wind " Heater, is adaptable for use on vehicles ; on ships with diesel engines on decks or otherwise exposed ; on engine-driven generators or compressors ; on engines of cranes, winches, or booms used for cargo handling on docks or materials handling elsewhere ; or, in any outdoors location where ambient temperatures fall below " practical " engine starting temperatures.

Heating of the interior of the engine is accomplished, in the Stewart-Warner system, by the circulation of clean air, heated to approximately 400° F, through the engine. In addition, heated air can be introduced



into the engine air induction system *via* the air cleaner, thus aiding combustion by warming the air and fuel vapour, and preventing condensation of the fuel on cold manifold and combustion chamber walls. Tests conducted on engines using heated induction air have resulted in starts after only a few revolutions of the engine, thereby imposing a minimum load on battery charge.

Lubricating oil may be heated by means of a heat exchanger built into or around the oil sump. A successful method used involves finned tubing routed through the oil sump, with air at 400° F, or the combustion heater exhaust, routed through the sump exchanger, to heat the oil.

Using a standard vehicle heater with a normal delivery of 20,000 BTU/hr, a 6-cylinder diesel engine, weighing over 3000 lb, has been started after less than one minute's cranking at 60 to 90 rpm, at temperatures from −25 to −65° F, using SAE 10-W oil. This engine was pre-heated from 25 to 75 minutes.

Because the heaters employed, in the case of trucks or other vehicles, are engine-mounted, although independently operated, the heat output, after cold weather starting has been accomplished, can be diverted to personnel heating, defrosting, cargo heating, etc., by means of simple diversion dampers, eliminating the need for other heating equipment on the vehicle.

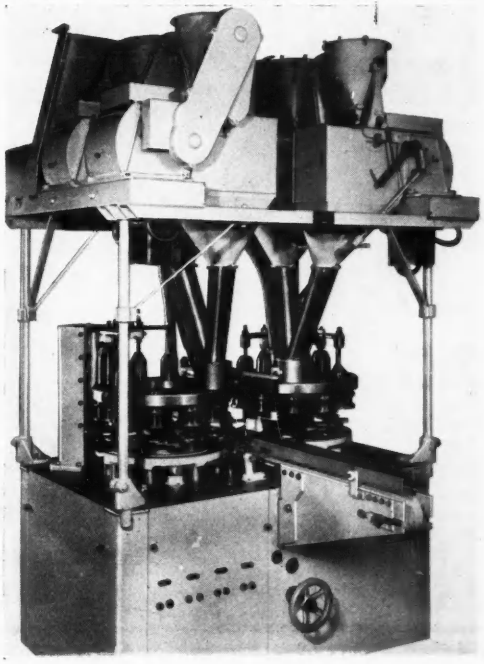
The illustration shows a typical installation fitted to a diesel engine.

FULLY AUTOMATIC POWDER-PACKING PLANT

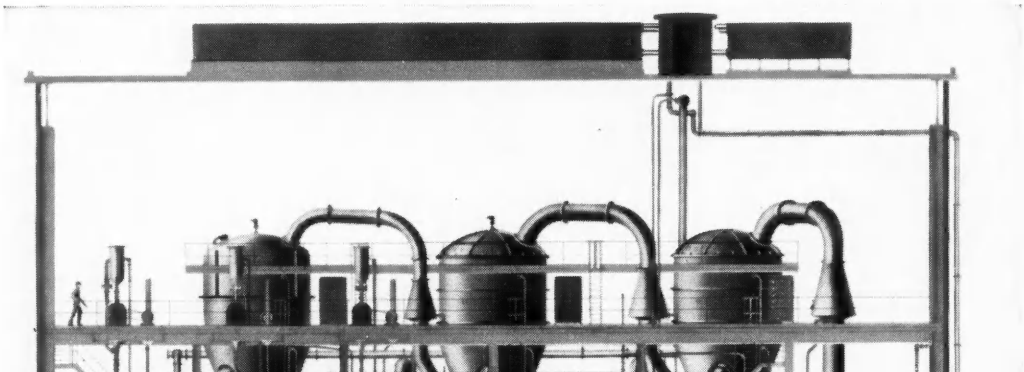
The precision weighing and filling into tins or containers of milk powders and similar powders which bulk above the container when filled, has always been considered to present very serious difficulties. A machine, which succeeds in combining really accurate weighing with the rapid filling of such powders, is announced by Autopack Limited, of Birmingham.

The tins are conveyed into the machine by a conveyor, which can link up with other machines, and are diverted into two rotors which feed them to the filling position, where the exact quantity of powder is weighed in from four accurate " Autopack " weighing machines giving an accuracy of 0·5 per cent overall tolerance, and weighing from ¼ to 1 lb of powder.

While it is being carried round to the outlet, vibration is applied to settle the material down to the required level in the container. Spring-loaded funnels with soft rubber washers are mounted on top of the containers, surplus material being retained by these funnels and the feed plates above them, and being vibrated down as the containers pass through the machine. In the



INDUSTRIAL CRYSTALLIZATION BY THE KRYSTAL PROCESS



TRIPLE EFFECT KRYSTAL EVAPORATOR INSTALLATION

This plant built mainly in solid nickel for the production of 300 tons/day of pure Sodium Chloride crystals, from well brine is typical of many multiple effect KRYSTAL installations, in operation throughout the world producing Sodium Chloride, Ammonium Sulphate, Ammonium Nitrate and other salts.

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final stages of the passage through the rotor, pressure is applied to complete the settling down of the powder. The filled containers are finally discharged from each rotor on to the outlet conveyor, which links up with the seaming machine.

Automatic controls ensure that no material can be discharged unless a container is actually in position, and that no double or half quantities can be discharged at any time during the cycle of operations. The complete machine (illustrated) is mounted on a substantial table and is self-contained with driving motor. Speeds of up to 70 containers per minute are possible, according to the weight of material and the size of the containers being handled. A slower speed machine can also be supplied, consisting of one rotor only, with a twin set of automatic weighing machines, giving an output speed of 30 to 35 containers per minute.

DIRECT WRITING POLAROGRAPH

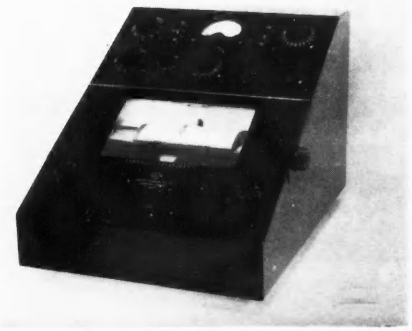
The Cambridge Direct Writing Polarograph, manufactured by the Cambridge Instrument Company, Limited, of London, S.W.1, has been designed for the rapid chemical analysis of solutions by an electrochemical method. It requires only a very small quantity of solution, which, as it is practically unaffected, can be used for repeated tests. The method employed is that largely developed by Heyrovsky and his co-workers, and is essentially as follows :—

From a jet immersed in the solution, a stream of mercury drops is allowed to fall into a pool of mercury. A variable voltage is applied between the jet and the pool, and the resulting electric current is measured. The voltage-current curve of the solution generally exhibits a series of " steps," the position of which on the voltage scale is a characteristic of the nature of the ions present in the solution, while, from the height of the " step," it is possible to measure the concentration of the ions by calibration under constant working conditions.

The instrument is equally well adapted for industrial use and for research. The recording unit is completely self-contained, and comprises a robust, direct-writing galvanometer with amplifier, a potentiometer, and the chart driving mechanism. The paper chart has a recording space of 75 mm on the current axis by 160 mm on the voltage axis, and is divided into 1 mm squares. The chart is driven by a synchronous motor, with a two-speed gear giving speeds of 15 mm or 3·75 mm per minute.

The dropping mercury electrode system consists of an electrolytic cell for holding the solution, a capillary tube, and a mercury reservoir, the position of which can be adjusted vertically, to give the correct mercury height for the capillary in use. For accurate measurements of current, necessitating constant temperature, a thermostat, controlling to within about 0·1° C, can be supplied. This is normally used at 25° C, but can be readily set at any temperature up to 35° C. Electrode vessels and cells can be supplied either for use in the stand or in the thermostat. The normal cell capacity of all types is about 2 millilitres, but larger cells, holding 20 ml, are available.

If desired, the instrument can be supplied with a Univector unit, enabling a pure a.c. voltage to be superimposed on the standard d.c. voltage applied to the dropping mercury system, thus producing polarograms of greater sensitivity.



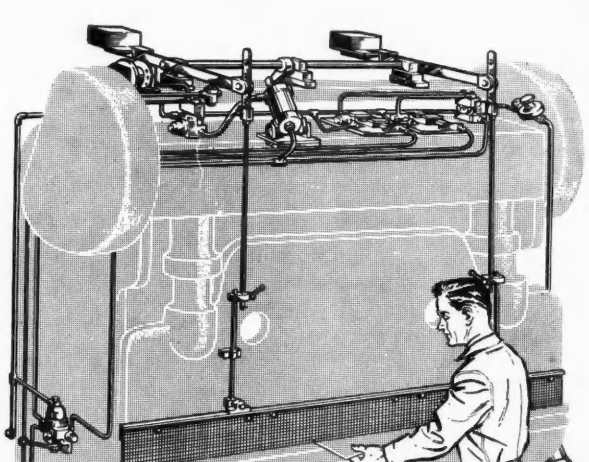
CYCLE CONTROLLER FOR PLASTICS INDUSTRY

The manufacture of articles by the moulding of thermosetting plastics has long been established, but the development of control equipment designed especially for this application has been somewhat retarded by the very nature of the process. However, what is claimed to be the last word in plastic moulding control is now announced by the Bristol Instrument Company, of Bristol, in the shape of their new cycle controller, Model 10CC × 500.

By careful design it has been possible to include in a standard 500 Series case up to ten process switches, available for opening and closing the press and other similar functions, together with an electrical process timer, process signalling lamps, and press buttons for starting and emergency resetting. Provision has also been made for the signal lamps and control buttons to be wired externally, if required, so that the instruments may be located in a position where damage or operator interference is eliminated. Timing inaccuracies have been virtually eliminated, down time of the press has been minimised, and versatility of operation is ensured.

The instrument consists of a rotating camshaft, upon which up to ten operating cams are mounted. The speed of rotation of the shaft can be readily altered by the substitution of a gear-change plate in the drive of the frequency-controlled motor. This is accomplished by the simple removal of two screws. Cycle durations from 20 seconds up to 5 minutes in 10-second steps are available and other speeds on application. The cams, which are engraved 0 to 100% from zero around their profiles, are slotted, to accommodate a number of operating dogs. The use of percentage graduations enables the dogs to be rapidly set up with respect to the rotation time of the camshaft, irrespective of the time cycle being used. Rapid removal of the camshaft provides maximum access for setting up the dogs on the

with SAFETY the watchword..



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Adaptable for any make of machine.
See the guard in operation at our own factory.

Controlled by an effective pneumatic system, one depression of clutch pedal operates both guard and machine.

1.2. Guard apron descends firstly by gravity to a set tolerance above workpiece and prevents further access to tool space before clutch can be engaged.

Guard is locked in down position under air pressure before clutch engages.

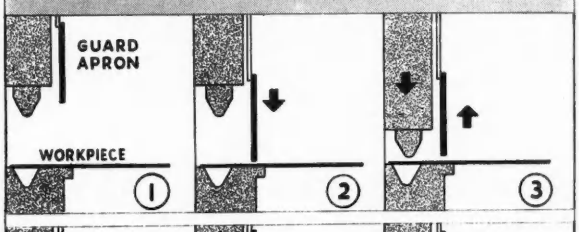
3.4. Guard starts to rise *immediately tools touch work piece.*

5.6. Workpiece is formed and withdrawn without guard interference.

SPECIAL SAFETY NOTE

Guard apron is sensitively balanced so that should it fall on operators' hands accidentally, no harm will result. Clutch will also not engage and machine cannot operate.

OPERATION SEQUENCE



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work bench. Should a number of standard repetitive cycles be required, additional camshafts can be supplied and slipped into position by opening the split bearings fitted, and exchanging the existing camshaft for the desired preset cycle. The dogs operating the process sequence are locked on to the cam by nuts, which can be rapidly slackened off and re-adjusted.

It has been found that timing inaccuracies occur where a number of operating switches are functioning at the same time. This is due to the friction of the operating faces of the cams on the switches or valves. To prevent this, the controller is so designed that contact between dogs rotating on the camshaft and the switches occurs during the change-over period only, resulting in a practically constant loading on the drive motor at minimum torque. For the major part of the cycle, the motor is required merely to rotate the shaft.

An important feature of the instrument is the resetting mechanism, which has been so designed that, by pressing the reset button, the control circuits are isolated and the camshaft reverses its direction of rotation and returns to zero. The completion of reset is signalled by coloured lamps and the pressing of the start button is all that is required to restart the sequence from zero. As a safety measure, the circuit is so arranged that the resetting mechanism is non-operative during the cure period.

During the cure, the controller stops and remains stationary for the timed period. Adjustments to the cure period can be readily made by altering the pointer on the dial of the process timer mounted on the front of the instrument. Once the period has expired, the controller restarts and the timer automatically resets for the next cycle.

The controller is entirely electrical and the control circuits are completely isolated from the functional circuits of the instrument so that, if preferred, low voltages only are used in the proximity of the press.

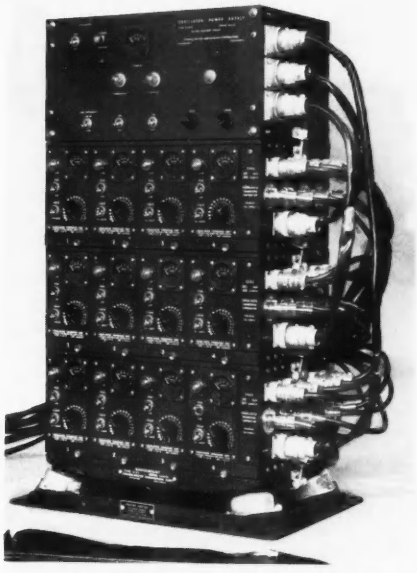
MULTI-CHANNEL AMPLIFIER SYSTEM

The unitised, multi-channel Amplifier System " D," manufactured by Consolidated Engineering Corporation, of Pasadena, California, now offers extended carrier-amplifier range and increased data capacity. Both linear-integrating and carrier amplifier units may be used in any combination up to a maximum of 12, to permit simultaneous use of self-generating and externally excited pick-ups. Physical phenomena in the 0-5000 cps range may be amplified and the system output coupled to any recording oscillograph equipped with galvanometers of matched characteristics.

Highly versatile, the system may be used with capacitance, inductance, reluctance, resistance, piezo-electric, and photo-electric types of transducers, as well as with types developed in the laboratory for specific test instrumentation requirements. Thus, a single oscillograph record may contain indications of strain, pressure, acceleration, vibratory displacement, and velocity. Rugged, lightweight construction and wide temperature operating range (—10° C to + 40° C ambient) permit use under varied conditions, including laboratory, field, and flight-test applications.

The single-channel amplifier units plug into stacking, four-channel capacity cases, with all input, output, and power connections made automatically upon insertion, to eliminate intricate wiring. Controls mounted on the front panel provide operating convenience.

The carrier amplifiers provide uniform frequency response ($\pm$ 2%) from input signals in the 0-600 cps range. Each incorporates a balance circuit for removing resistive or reactive unbalance from either two- or four-arm bridges. The null-balance type bridge circuit maintains linearity under all operating conditions, cancelling temperature effects and providing a zero-reference point unaffected by attenuator setting. A



phase-sensitive demodulator provides directional sense for the output signal. Full-scale output may be obtained from input signals in the 1 millivolt to 1 volt rms range.

Flat frequency response of the linear-integrating amplifiers is as follows :—*Linear*, $\pm$ 5% from 5 to 5000 cps ; *integrating*, $\pm$ 6% from 5 to 5000 cps (low range), and $\pm$ 6% from 50 to 5000 cps (high range). Input signals for linear amplification may be as low as 3 mV, while those required for integrating operation are 190 mV (low range) and 19 mV (high range). Sufficient power for the complete operation of as many as 12 amplifier channels is provided by the system's new oscillator-power supply. Excitation of pick-ups used with the system is accomplished by means of the oscillator section's 10 V, 3 kc, 12 W carrier output.

EXHAUST FANS.

A new series of exhaust fans, coupled with a new form of ducting, has been introduced by Turner & Brown Ltd., of Bolton. Known as the " Turbro " range of centrifugal fans, they and the ducting are almost entirely constructed from a recently developed grade of rigid plastic industrial sheet (VYBAK VR.215), based upon polyvinyl chloride (P.V.C.), and supplied by Bakelite Limited. This material has high impact and tensile strength, good dimensional stability, and exceptional resistance to chemical attack or weathering. As a result, the life of any installation fabricated from it greatly exceeds that of " protected metals."

The fans range from the " Turbro " Junior (illustrated), with an extraction capacity of 300-330 cfm and intended for use with fume cupboards, small laboratories, etc., through a variety of sizes to suit individual requirements up to a maximum displacement of 15,000 cfm.

In these fans, the casing, impeller, and impeller shaft are made entirely from VYBAK Rigid Sheet, and the whole is so designed that no metallic parts are in contact with corrosive fumes. The casing itself conforms to existing principles, but is bolted to an outside frame of metal, and this arrangement allows the outlet to have no less than sixteen equi-arc positions, as well as permit-

a new thin wall bearing

We are now free to announce the availability of Dualloys Thin Wall Bearings. These will exhibit the same dependable quality and capacity for long service which characterise our thick wall bearings and will enjoy an equal reputation. Our Company and its personnel have had long and successful experience of bearing manufacture.

Our new thin wall bearings result from this specialist experience.

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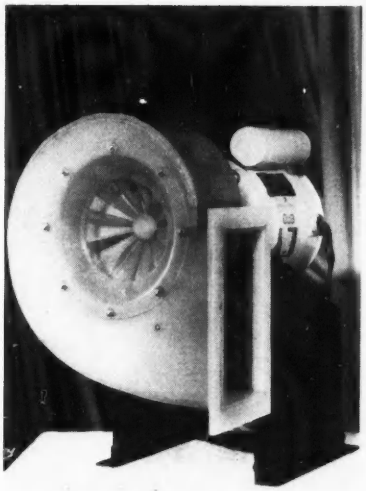
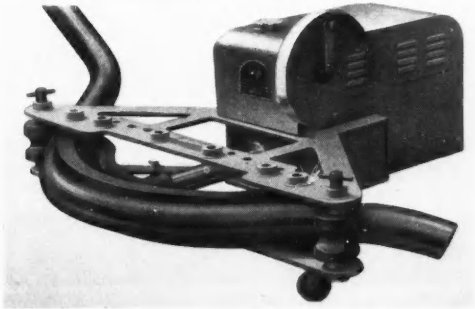


ting the fan to be easily coupled with existing ducting or to be fitted into small, enclosed areas. The impeller has twelve blades round a central boss, all made from the same material, and a hollow shaft to allow the introduction of the keyed steel shaft from the motor. All the equipment is designed in strict accordance with aerodynamic principles, and a long series of tests has shown it to be virtually noiseless in operation.

The VYBAK P.V.C. sheet used in this design has been specially developed to meet the need in industry for a tough constructional material which can be machined and fabricated by methods similar to those used for sheet metals, though considerably more easily. It can be sawn, drilled, routed, and milled, and may also be formed by heating above its softening point and cooling in contact with the desired contour. In addition, it can be " hot gas " welded with matching rod. It thus lends itself readily to the fabrication of all kinds of chemical plant—tanks, ducting, etc.—though, being thermoplastic, it should not be used unsupported at temperatures above 60° C. Up to this degree, however, it remains perfectly inert, with the properties already enumerated, and it may be noted that tubing and rod extruded from similar compounds for pipe-lines, valves, etc., are also obtainable.

MOTORISED HYDRAULIC TUBE BENDER.

To meet modern trends, Messrs. Chamberlain Industries Limited, of Leyton, London, E.10, announce that considerable improvements have now been incorporated in their new model M/4 " Staffa " portable motorised hydraulic tube bender.



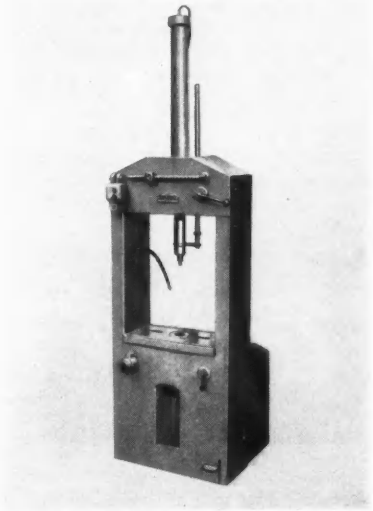
By adopting a simplified form of hydraulic pump, the bending speed has been so increased that, when powered by a 2 hp motor, the 15 ton ram thrusts forward at a speed of 21″ per minute. This means that 4″ nominal bore steam and gas tubes, the largest tubes the machine can accommodate, are now bent to an angle of 90 deg cold and unloaded in 1 minute instead of in 4 minutes, as required on the old design.

In addition to the existing 3-way control valve, a 2-button direct-on-line starter, with thermal overload trips, has now been provided, to enable the operator to have complete control of the machine within his immediate reach. The patent take-off arms, exclusive to " Staffa " products, eliminate the old-fashioned, labour wasting and often dangerous methods of tube removal after bending by means of wedges, hammers, etc. This operation is now carried out automatically without any effort at all on the part of the operator, and fatigue is thus reduced to a minimum.

All classes of steam and gas tubes can be bent expeditiously by means of accurately machined cast steel formers, which can be provided for tubes from ⅜″ to 4″ nominal bores. Electrical conduits up to 2″ diameter, heavy hydraulic tubes up to 3″ diameter, and black mild steel flat bars up to 7″ × ¾″, can also be bent up to 90 deg by the use of additional formers.

HYDRAULIC POWER PRESSES

Made in three sizes, and providing working pressures of 9, 20, and 50 tons respectively, the all-steel welded " Marlco " hydraulic power presses, manufactured by W. H. Marley & Co. Limited, of London, N.11, offer maximum rigidity with minimum weight, the strength of any part being far beyond the capacity of the machine.



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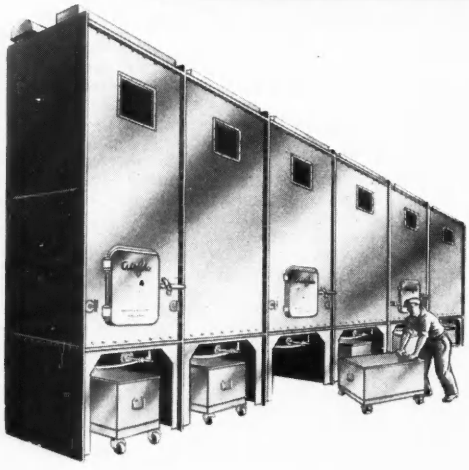

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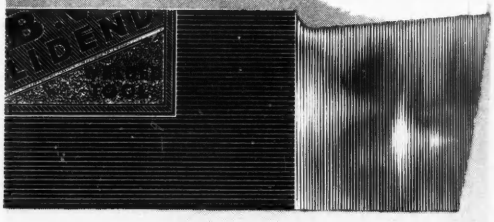

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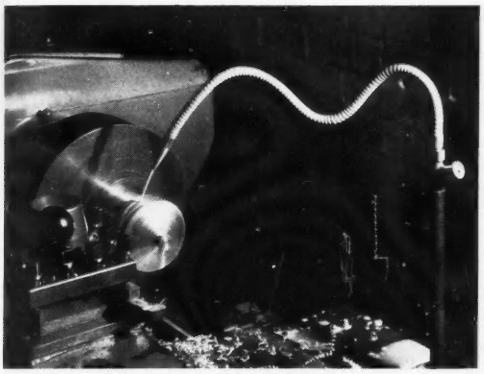
The pump is compact in design, and includes an automatic lubrication system to all moving parts.

"RIGID FLEXIBLE" TUBING FOR SUDS PUMPS

To enable a lathe operator to effect instantaneous adjustment of the direction of flow of cooling and lubricating fluid over a cutting tool and, at the same time, to dispense with the need for multiple universal joints



(all of which can leak), a "rigid flexible" tubing is being manufactured for use with suds pumps, by Creators, Ltd., of Sheerwater, Woking.

Whereas most brass suds pump pipes, as used on lathes to-day, have as many as fifteen or twenty independent brass fittings on a single eighteen inch length, the new form of tubing is in one piece, without joints, and has no laminations to come apart after continual flexing. It is manufactured with a nozzle at one end and a connection for fitting to a suds pump at the other, as shown in the illustration. The tubing is resistant to petrol, grease, oil, water, and almost all acids and alkalis.

The tubing, known as "Rigiflex," is made from a special synthetic compound, which is also abrasion-proof, and has a 120-ton tensile steel spring built into the wall of the tube in combination with a specially manufactured alloy to give it rigidity. As a result, the tubing can be bent between thumb and forefinger, but will remain rigidly in the position determined by the operator.

PORTABLE WEIGHING MACHINE

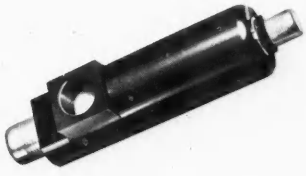
The largest capacity portable weighing device in the world, to weigh up to 200 tons, has been tested at Lloyd's Proving House, Netherton, where it was subjected to a 50 per cent overload—equivalent to a total weight strain of 300 tons.

The instrument, which itself weighs more than six tons, is an outsize development of the crane weigher made by Geo. Salter & Co., Ltd., of West Bromwich. It has been made especially for the English Steel Corporation, of Sheffield, and will be used for weighing castings and forgings of nearly 200 tons as they are lifted and moved for loading. This particular weigher is 12 ft high, yet the actual movement in the weighing mechanism is only one-eighth of an inch, graduations of one ton up to 200 being controlled by the flexing of two Belleville washers opposed to each other as two concave surfaces. Hitherto, the largest Salter crane weigher made has had a capacity of 120 tons.

REDUCING VALVES FOR AIRCRAFT

A new range of reducing valves for aircraft, capable of controlling and stabilising supplies of hot air tapped from the compressor of a gas turbine engine, has just been introduced by The Hymatic Engineering Co. Ltd., of Redditch, Worcs. The output from these valves can be used for such applications as pressurising the tanks to transfer or jettison fuel and to prevent fuel losses by boiling at high altitudes and for space and component heating or pressurisation.

Known as the PS.48 series, these new valves can stabilise inlet pressures of up to 200 psi at constant adjustable outlet pressures of up to 35 psi, within provisional temperature limits of — 40° C to 250° C. No organic packing materials are employed and there are no limitations arising from differential expansion. Pressure control is achieved by balancing air pressure on a piston against an adjustable spring load. As the piston is not packed, a small leak is unavoidable and a vent connection is provided to allow the leakage air to be piped away.



A simple, but highly effective, means of balance and compensation ensures that the closely controlled outlet pressure is almost unaffected by variations in inlet pressure. In most cases a fuel tank pressure can be held to ± 0·25 psi from the nominal setting for flows up to at least 15 cfm of free air—taking into account even unavoidable pipe losses between valve and tank. This is achieved by arranging for the reduced pressure at the valve to rise with increasing flow by an amount approximately equal to the pressure loss in the pipe line to the tank.

This type of valve, which weighs 1·4 lb, is suitable for duties where contamination with gas turbine fuels is likely, as the casing is pressure-tight, and hence there is no risk of fuel leakage into the surrounding aircraft structure.

ERRATUM.

On page 478 of our December 1953 issue, reference was made to "The first diesel compressor with a flywheel-type synchronous motor . . ." In this context, the word "diesel" should have been omitted, and the title of the item should have read "Atlas Diesel Compressor," since the machine described is not in any sense a diesel compressor, "Atlas Diesel" referring to the company which manufactured it.

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CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

BEARING AND BEARING MATERIALS

Functions of Materials in Bearing Operation.

By P. P. Love, P. G. Forrester, and A. E. Burke. (From a paper presented at a meeting of the *Automobile Division of the Institution of Mechanical Engineers, London*, December 8, 1953, 8 pages, 22 illustrations.)

The ranges of operating conditions in reciprocating internal combustion engines and the continual demand for higher performance frequently prevent the elegant solution of design problems. This is because the satisfactory operation of many of the components of the engines depends on a combination of physical mechanisms, each of which is fundamentally limited. The design of bearings presents such problems, necessitating compromise and involving a large degree of judgment on the part of the designer.

The objects of this paper are to outline these problems, to describe some of the compromises, and to indicate, with reference to examples, how such problems are being tackled quantitatively by the bearing designer. The paper is limited to the consideration of plain bearings, particularly main bearings and connecting-rod big-end bearings.

This paper considers the numerous factors affecting the operation of such bearings; the problems of bearing design, from the aspect of the selection of the various materials which are combined in the construction of a bearing assembly, are discussed. An attempt is made to bring together conclusions reached by studying the factors referred to singly or in groups, and the performance of bearings in practice. The latter is based on a study in summary of the three types of bearing failure, i.e., seizure, excessive wear, and mechanical breakdown. Comment on recent work by Lunn and Roach is made, and a working hypothesis on the effective fatigue strength of a bearing lining is proposed.

The conclusions reached are that the factors influencing the performance of a bearing are highly complex, and that the choice of material, and the design, still rest to a large extent on empirical knowledge.

The work which has been carried out in a number of different fields is, however, now beginning to fall into place, making it possible to construct much more general hypotheses concerning bearing operation. In addition, much more satisfactory apparatus and experimental techniques have, in recent years, been developed for testing hypotheses. Fairly rapid advance may therefore be expected.

BOILERS

Quick-Starting of Large High-Pressure High-Temperature Boilers.

By J. C. Falkner. (From *Transactions of the ASME, U.S.A.*, Vol. 75, No. 8, November 1953, pp. 1407-1460, 95 illustrations.)

In the near future, Consolidated Edison's generating stations will be faced with routine week-end 24 and 48-hr shutdowns of large, single-unit, high-pressure, high-temperature turbines and boilers. It is with this prospective situation in mind, together with a conviction that quick-starting from cold of large high-pressure boilers, when properly handled, is less rigorous on the expanding boiler structure than present 5 to 6-hr starts, that this investigation was carried out by the author.

The results reported in this paper demonstrate how the basic objective of starting 1,000,000 lb/hr, high-pressure, high-temperature boilers from cold to a steam condition suitable for turbine synchronisation in one hour has been accomplished successfully without any shortening of normally expected superheater tube life, and with drum tangential stresses less than those during slow-starting, except at the drum ends. In these local areas, minor drum internal-baffle changes could be made, and these should reduce the stresses well below permissible values.

The 1-hr starting time, whilst apparently not the minimum possible, is, in the judgment of the author, a reasonable minimum time to permit a complete check by the operators of boiler and turbine conditions during the starting period.

It is hoped that the data presented in this paper will be useful to other utility operators, when their system growth and number of installations of high-pressure high-temperature units reach the point where week-end shutdowns become necessary; and also to boiler designers for consideration of provisions in present and future designs for improved circulation in the drum ends, and to permit them to issue more definite recommendations to operators with regard to maximum permissible drum-metal temperature spreads at the various drum pressures during the starting period.

ELECTRIC MACHINERY

Characteristics of the Induction Frequency Converter.

By R. C. Moore. (From *Allis-Chalmers Electrical Review, U.S.A.*, Vol. 18, No. 3, 3rd Quarter, 1953, pp. 27-29, 7 illustrations.)

The wound-rotor induction motor is widely used because speed change is easily effected by varying an external resistance, electrically connected to the rotor. Slip rings are necessary to dissipate resistance losses outside the motor and to simplify resistor step adjustments. In applications of this type, the power delivered by the motor shaft is of principal interest. Rotor resistance losses are incidental and are tolerated in order to obtain speed variations. However, if the power in the rotor circuit is utilised, instead of being wasted in resistors, the converter principle of the induction motor is obtained.

When the stator winding of the converter is connected to a power supply of constant voltage and frequency, a rotating magnetic field is set up in the air gap and induces voltage in the rotor winding. At standstill, the frequency of this induced voltage is the same as that of the stator and its magnitude depends on the design value of turns ratio between the stator and rotor windings.

The frequency at which the converter delivers power is determined by the slip of the rotor with respect to the rotating magnetic field. Induced rotor voltage and frequency are dependent on rotor speed, while the ratio of induced rotor voltage to its frequency is constant, regardless of rotor speed.

For applications requiring accurate regulation of variable speeds within a specified range of relatively low shaft speeds, the induction frequency converter is definitely practical. Although it is essentially a wound-

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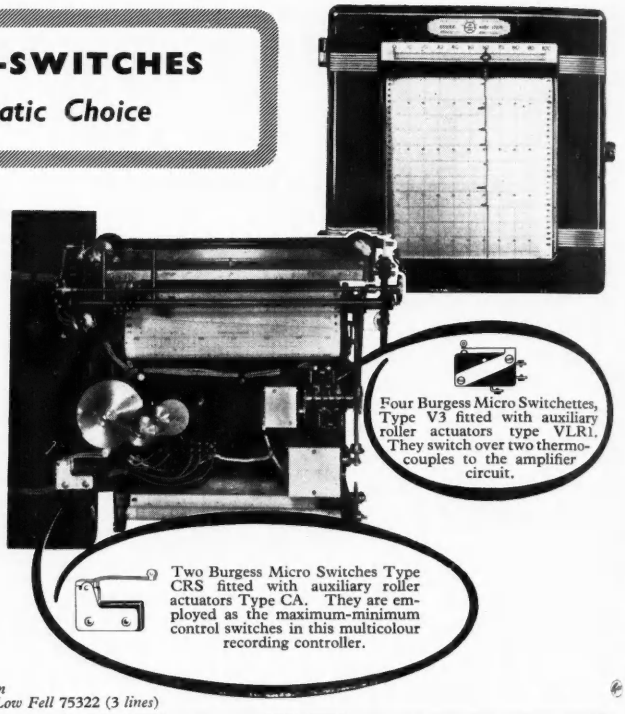

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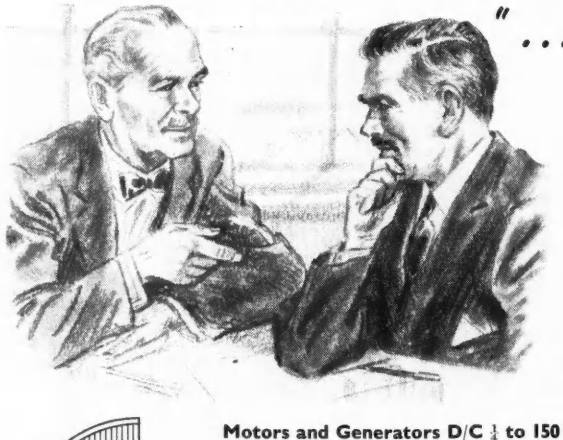

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rotor motor, modifications in design and construction are necessary, and these modifications depend on the specific application. Careful consideration must be given to the converter design, to ensure a system that will operate successfully.

ILLUMINATING ENGINEERING.

Frequency and Fluorescent Lamps.

By D. E. SPENCER. (From *Electrical Engineering, U.S.A.*, Vol. 72, No. 12, December 1953, pp. 1066-1070, 6 illustrations.)

WITH the development of a better understanding of electric circuits and electromagnetic fields, engineers have found that higher frequencies than the standard 50 to 60 cps are preferable in many applications. For instance, aircraft equipment is normally designed for higher frequencies, such as 600 cps, thereby reducing the weight of synchronous equipment, as compared with similar 50 or 60 cps equipment. Electric furnaces for induction heating of metals are available with frequencies of 1000, 3000, and 10,000 cps.

Although the ordinary commercial frequency was developed to meet the needs of incandescent lamps, it is theoretically unsuitable for the operation of fluorescent lamps. To obtain best performance, fluorescent lamps should be operated at a much higher frequency. While the dynamic thermal equilibrium of an incandescent lamp is satisfactorily approximated at a frequency of 50 to 60 cps, the dynamic characteristics of fluorescent lamps, under ordinary conditions of operation, are relatively complicated, because inertia effects are comparatively small. Frequencies above 60 cps are required to produce dynamic equilibrium.

Optimum operation of fluorescent lamps is obtained at frequencies between 3000 and 10,000 cps. If such lamps are operated, for example, at 3000 cps, the system is both practical and economical. Among other advantages derived from the use of higher frequencies are the following :—Linear volt-ampere characteristics for fluorescent lamps ; sinusoidal waveform ; larger lumen output at rated power input (between 6 and 15% increase) ; no visible flicker and no stroboscopic effect ; quick starting ; no audible ballast hum ; no radio-frequency interference ; reduction in weight of metal required for lamp auxiliaries ; and reduction in overall cost of lighting system.

The engineer who is designing any large lighting system should give careful consideration to the advisability of increasing the frequency to at least 3000 cps.

LOCOMOTIVES

Some Questions about the Steam Locomotive.

By W. A. TUPLIN. (From a paper presented at a meeting of the *Institution of Locomotive Engineers, London*, December 16, 1953, 29 pages, 11 illustrations.)

THIS paper touches on a few casually selected items out of the very large number presented by the steam locomotive for discussion, and ranges from basic principles to practical details. In most machinery, however, the details are important and perhaps especially so where fluid pressure is a major factor, because leakage past pistons and valves can be more important than the effect of any reasonable change in major dimensions. Overdue washing-out of the boiler may drastically reduce power development, a broken oil pipe may bring a run to a premature end, difficulty of access to a lubricating point may induce the man concerned to risk omitting a re-fill for once, and uncomfortable conditions for the men on an engine may disincline them to take the little extra trouble that may be required to extract a time-keeping performance from it. Thus, practical details may be more important than fundamentals in the day-to-day running of locomotives.

The common occurrence of " good " and " bad " engines of nominally identical dimensions has long been accepted as inevitable, but with the reduction of locomotive stocks to a small number of standard classes it may be practicable to challenge the inevitable. For example, a small staff of " trouble-shooters " might take an engine stigmatised by enginemen as bad, apply some tests to find out whether it is in fact bad, and then check over all important dimensions with special precision, in order to find just where the engine is below standard quality in material or accuracy. Something of the sort has no doubt been attempted by shed maintenance staff, probably in many cases without success, but the problem may nevertheless usually yield to expert staff properly equipped for detection and correction.

It seems certain that the present general form of the steam locomotive is the best compromise between fundamental ideals and practical possibilities. This paper questions whether any useful thermodynamic gain is to be expected from raising steam pressures or temperatures, and suggests that the best designs can be expected only from those who regularly re-acquaint themselves with the difficulties encountered in building locomotives and maintaining and running them under working conditions. The basic principles are simple, but detail design for economy in manufacture and service still leaves room for ingenuity and rigorous testing.

ROLLING MILL PRACTICE

The Calculation of Roll Force and Torque in Hot Rolling Mills.

By R. B. SIMS. (From an advance copy of a paper submitted to the *Institution of Mechanical Engineers, London*, December, 1953, 12 pages, 12 illustrations.)

THE exact solution of the rolling process is not known ; even the form of the slip-line field in the plastic material between the rolls is still a matter for conjecture. A solution to the problem of strip rolling has been attempted by Orowan (1943), who based his analysis on the simplifying assumption that the deformation resembled the compression between rough inclined platens, a problem which had been solved in part by Nadai (1931). Although this assumption is not strictly correct, Orowan has shown that it gives a closer approximation to the pressure distribution in the arc of contact than earlier equations (von Kármán, 1925 ; Siebel, 1925), particularly for hot rolling.

Although used as a standard against which other theories of rolling are often compared, Orowan's equations to the roll pressure have not been applied generally to mill design and operation because of the time needed to complete the numerical calculations for a set of passes. The present analysis provides a method of calculating roll load and torque in the case of hot rolling, in which the time required to compute the roll force and torque in a pass schedule is reduced to a few minutes, with little loss of accuracy in comparison with a calculation carried out using Orowan's equations.

The assumption of plane deformation has been made in deriving the proposed equations. They may be applied, therefore, to passes where the width thickness ratio for the material is greater than 5 and, preferably, is greater than 10. There is a wide range of products rolled where the width/thickness ratio is less than 5. Billets, for instance, are rolled nearly square in section, and this departure from plan deformation makes a theoretical solution almost impossible. This problem has been examined experimentally by the rolling of bars of pure lead in a mill equipped with roll load and torque meters, and an empirical solution is suggested from the results.

In this paper, equations are derived for the normal roll pressure, specific roll load, and torque in hot rolling mills, using the condition for plastic deformation in rolling derived by Orowan, together with von Kármán's

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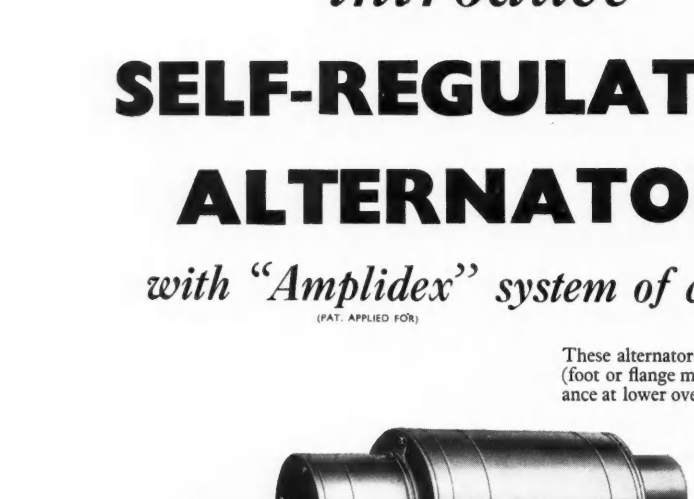

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equation of equilibrium. Although applying strictly to the rolling of ideal plastic-rigid materials, these equations may be applied to the rolling of materials which strain-harden by using a mean value of the yield stress in the pass.

The equations have been checked against measurements made when rolling pure lead at room temperatures, and against the results of the experiments on steel at elevated temperatures carried out at Holfors. There is close agreement between the calculated and measured roll loads, but the roll torque is over-estimated slightly by the theory, above reductions of about 30 per cent in thickness.

STANDARDS AND SPECIFICATIONS

Technical Features of the New British Standard System of Limits and Fits.

By H. G. CONWAY. (From a paper presented at a meeting of the *Institution of Mechanical Engineers, London*, December 18, 1953, 15 pages, 15 illustrations.)

ONE of the most important tools of the design engineer is a standard used for determining and specifying tolerances and fits for all classes of products manufactured to interchangeable limits. The publication, therefore, of a new British Standard for limits and fits in recent months is a matter of importance to all British designers and production men. The publication of Part 1 of B.S. 1916 in May, 1953, is only the third occasion on which a British Standard for limits and fits has been issued, the previous occasions being in 1924 and 1906.

Standardisation of nominal diameters is a necessary preliminary, and, although practice may vary in the use of common fractional or decimal sizes, the bulk of modern design work applies limits and tolerances to common, and frequently used, sizes; Part 11 of B.S. 1916 contains official recommendations in this matter. The main purpose of a limit and fit standard is to enable a degree of standardisation of certain types of tool and gauge to be achieved, either locally in a firm, in the case of an industrial standard, or nationally throughout the country, in the case of a British Standard. It is a common experience, notwithstanding, that even where a firm does use a tolerance standard, it is possible to find in tool or gauge stores a wide variety of reamers or plug gauges of almost, but not quite, identical dimensions. A good national standard, conscientiously applied, is the best means of correcting this state of affairs.

Another advantage of a limits and fits system is that it enables guidance to be given on the specification of limits by recommending associations of hole and shaft, thus giving the designer a reasonable selection to choose from, rather than allowing him to create fits from his imagination, to the detriment of tool and gauge stocks, and often the cost of production.

This paper discusses the new British Standard for limits and fits for engineering, outlining in particular its technical features and explaining how the system has been built up. A brief historical review of other systems is made, with references to their faults. The prospects of adoption of an equivalent system by the United States and a corresponding decision already taken by Canada are mentioned.

The paper goes on to discuss the theoretical requirements of a good tolerance system and then compares the new standard with the theoretical desiderata. The technical reason for each particular diameter step, tolerance value, or shaft or hole allowance is given, supplementing the necessarily bare data given in the standard itself.

Indications are given of the future extensions of the system likely to be made following international discussions in relation to tolerances for small diameters as used in the horological industry, tolerances for precision fits and fine quality gauges, and tolerances for large diameters up to about 6 feet. The practical difficulties in determining and using tolerances in diameters above 20 inches are considered in some detail, and a plea is made for discussion and information on this matter.

STRENGTH OF MATERIALS

Approximate Approach to the Torsion Problem of a Shaft with a Circumferential Notch.

By H. OKUBO. (From *The Reports of the Institute of High-Speed Mechanics, Tôhoku University, Japan*, Vol. 3, 1953, pp. 1-9, 5 illustrations.)

THE torsion problem of a bar with varying circular section has been treated by several investigators over a long period. Usually, the solution covering all points in a shaft is found first, and then the maximum stress is obtained. Accordingly, the analysis becomes complicated and thus only a few cases have been treated completely.

It is essential from the technological point of view, however, to find the stresses around a notch, rather than the stresses at every point in a shaft. The approach employed in this paper is somewhat different from others, and the approximate values for the stresses and the twist on the surface of a shaft are found directly without solving the problem completely.

A simple method is presented for the approximate determination of the stresses and twist on the surface of a shaft with a circumferential notch. The lines of shearing stress near the surface are replaced by the corresponding streamlines of a uniform flow in an infinite domain. Theoretically, the approximation is comprehensible only in the limit case, where the dimensions of the notch are infinitely small compared with those of the shaft.

As an example, the problem of a shaft with a semi-circular notch has been evaluated numerically. Contrary to expectations, the results closely agree with those of the exact solution, even in the cases of moderate notch dimensions. This fact shows that the lines of shearing stress at the points near the surface are not affected appreciably by the relative dimensions of the notch, inasmuch as the dimensions of the notch may be considered small compared with those of the shaft. This consideration simplifies the analysis considerably, since the streamlines for various cases have been investigated extensively and these results can be immediately applicable to the present problem.

The solution for a semi-elliptical notch has been obtained in this way. Formulae for maximum stress, where the depth and the radius of curvature of the notch are specified, and also for the twist on the surface of the shaft, have been derived in simple forms.

Plastic Collapse of Thin Rings.

By CHINTSUN HWANG. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 20, No. 12, December, 1953, pp. 819-826, 845, 6 illustrations.)

THE elastic stress analysis of a redundant structure under steadily increasing loads, usually a tedious task, is applicable only when the stresses are below the yield limit. The structure may be said to have failed when the stresses in some locations reach the yield stress. Another way of defining the failure condition depends upon the deformation of the structure. It may be said that the structure fails when it yields completely at several locations and collapses as a mechanism. Thus, to study the failure of a structure, all that is necessary is to analyse the possible ways of total collapse of the structure.

When several concentrated or distributed loads are applied on a circular or elliptical ring and are increased proportionally, the ring first yields at some locations and, at the final stage, collapses as a mechanism. The collapse of a ring cannot take place until the number of yield joints developed in the ring exceeds its number of redundancies. In this paper, the configuration of the collapse mechanism, the corresponding collapse load of

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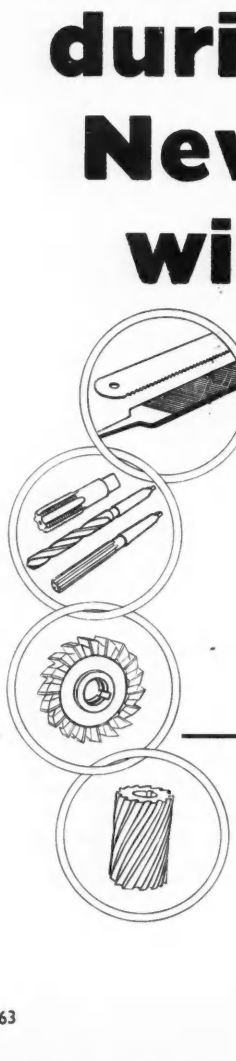

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rings, and the deformations of a circular ring immediately before plastic collapse takes place, are studied.

For rings in which the heights of the cross-section are small, compared with their overall dimensions, the stresses are essentially due to flexure of the ring segments when the ring is under the action of concentrated forces. The stresses due to axial and shear forces are relatively small and may be neglected. Furthermore, at the instant of plastic collapse, the deformation of the ring as a mechanism is unlimited if no strain-hardening of the material in the plastic state is assumed. In parts of the ring where the sections are still elastic, or partly elastic and partly plastic, the deformation is contained and may be neglected. Thus, the change in geometry of the ring is disregarded; the ring is considered as a mechanism made of perfectly rigid members, connected by yield joints offering constant resisting moments. The positions of these yield joints and the corresponding collapse load are found for several typical loading conditions.

MECHANISM OF COMBUSTION OF GUNPOWDERS AND EXPLOSIVES

(*Concluded from page* 14)

where v = rate of combustion in mm/sec, p = pressure in atmospheres absolute, and t = initial temperature in C of the gelatine dynamite. At pressures below atmospheric, it was found that the measured points were situated slightly off the log v line for 20° C. A straight line, running as nearly as possible through the test points at 20° C, was drawn over the entire range of pressures, and this gave the values $b = 0{\cdot}82$ and $A = 0{\cdot}53$. Thus, it appears probable that A and b vary somewhat with pressure.

The percentage variation between the calculated and observed values was moderate, however, even when the original constants were used for the entire range of pressures.

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COMPOUND GAS PRIME MOVERS

(*Concluded from page* 8)

Despite the fact that the thermodynamic principles involved have been understood for a long time, the development of compound gas prime movers has been slow. To-day, the subject merits attention more than ever because, in recent years, engineering has been enriched by several devices, in which the principles of compounding have been put into practice. Foremost among these is the gas turbine, as developed for pure gas-turbine engines and for supercharging with the aid of the exhaust energy of piston engines. The next acquisition has been the free-piston gas generator, originated by Pescara. This engine became a practical reality, mainly through the perseverance of a group of engineers working in France under Huber, but is at present actively pursued both in this country (Messrs. Alan Muntz, Ltd.) and in America. An original British contribution is the highly supercharged two-stroke valveless compression-ignition reciprocating crankshaft engine, nursed by Sir Harry Ricardo and matured in the Napier Nomad aero-engine, to-day the most successful prototype of the geared compound prime mover.

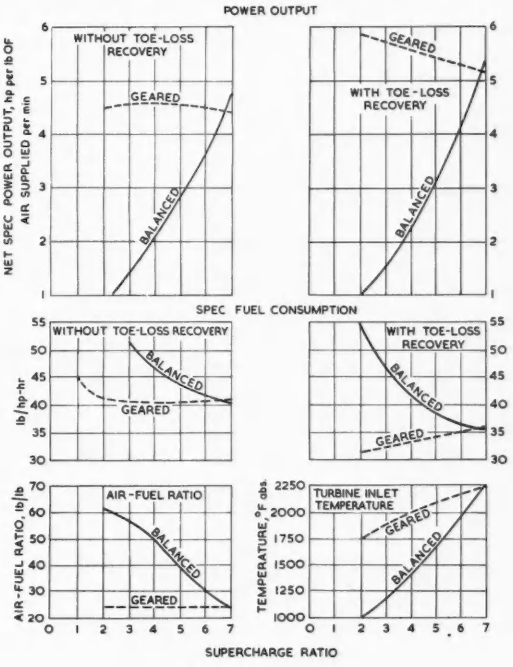

Fig. 3.

Having reached this stage of development and, aided by subsidiary lines of progress, such as practical, efficient, high-pressure, high-speed rotary displacement compressors, in the shape of the Lysholm-Howden-Elliott compressor, we may now look forward to the evolution of the compounding principle as a new phase in heat engineering.

In this review we have endeavoured to simplify the pattern of possibilities by using the broadest principles of classification. In practice, however, such principles are not always easy to apply. Thus, isothermal processes can often be approximated only by a number of steps consisting of adiabatic and constant-pressure heat addition or rejection. Stepped processes require a multiplicity of units. Moreover, even if the most appropriate cycle for economy in the production of power can be generally recognised, in many prime mover installations some of the factors enumerated earlier, apart from the fuel economy and weight cost factor, can be decisive.

To-day, we seem to be on the threshold of the "gas-turbine age." As a matter of fact, it is hard to believe that, although the first gas-turbine patent was actually granted in 1791, the gas turbine remained an outsider even after the steam turbine became prominent in power generation and ship propulsion. This historical reminder should teach us to pay more attention to other developments which, like the gas turbine, have remained on the fringe of competitive success for a generation, if not more. Certainly, the economic stakes of prime mover engineering are very high indeed.

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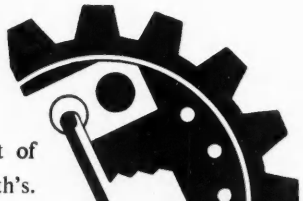

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NEWS OF THE MONTH

NEW YEAR HONOURS

The New Years Honours List, published on January 1st, contains the names of many engineers, industrialists and scientists. It includes the following names :—

KNIGHTS BACHELOR

Donald F. Anderson, chairman, Shipping Federation, and President, Chamber of Shipping of the United Kingdom ; **George F. Earle, C.B.E.,** chairman, Associated Portland Cement Manufacturers, Ltd. ; **John B. Elliot,** chairman, London Transport Executive ; **Ernest H. Lever,** chairman and chief executive, Steel Company of Wales, Ltd. ; **Oliver Lyle, O.B.E.,** for services in promoting fuel efficiency ; **Herbert J. B. Manzoni, C.B.E.,** city engineer and surveyor, Birmingham ; **Edward T. Paris, C.B.,** chief scientific adviser, Home Office ; **Walter C. Puckey,** formerly deputy controller of supplies (air), Ministry of Supply ; **William G. Radley, C.B.E.,** engineer-in-chief, General Post Office ; **John O. Sanders, C.M.G.,** general manager, Malayan Railway, and member for Railways and Ports, Federation of Malaya ; **Kenneth D. L. Sinclair, D.L.,** chairman, Belfast Harbour Commissioners ; **Lawrence J. Wackett,** for services to the aircraft industry in Australia.

ORDER OF THE BATH

K.C.B. **Sir James R. C. Helmore, K.C.M.G.,** Permanent Secretary, Ministry of Supply ; **Victor G. Shepheard, C.B.,** director of naval construction, Admiralty.

C.B. **A. T. Barnard, O.B.E.,** chief superintendent, Royal Ordnance Factories, Woolwich ; **M. P. Murray,** under-secretary, Ministry of Fuel and Power ; **Rear-Admiral (E) Leopold E. Rebbeck ; H. J. Watson,** deputy director, dockyards, Admiralty ; **Engineer Rear-Admiral J. W. Wishart.**

ROYAL VICTORIAN ORDER

K.C.V.O. **James McFadyen McNeill, C.B.E., M.C.,** managing director, John Brown and Co., Ltd., Clydebank.

ORDER OF SAINT MICHAEL AND SAINT GEORGE

C.M.G. **N. C. Robertson, M.B.E.,** director-general of electronics production, Ministry of Supply ; **I. Clunies-Ross,** chairman, Scientific and Industrial Research Organisation, Australia.

ORDER OF THE BRITISH EMPIRE

K.B.E. **Leonard P. Lord,** chairman and managing director, British Motor Corporation, Ltd. ; **S. C. Mitchell, C.B., O.B.E., R.N.(ret.),** controller of guided weapons and electronics, Ministry of Supply.

C.B.E. **G. T. Bussey,** assistant secretary, Ministry of Fuel and Power ; **N. C. Chapling,** managing director, Cable and Wireless, Ltd. ; **St. J. de H. Elstub,** director, Metal Division, Imperial Chemical Industries, Ltd. ; **W. G. Fergusson,** assistant secretary, Ministry of Materials ; **R. D. Gwyther, M.C., M.I.C.E.,** senior partner, Coode and Partners, consulting engineers, London ; **E. J. Holford-Strevens,** joint controller for North-Western region, Board of Trade and Ministry of Supply ; **B. P. Ingamells,** director, merchant shipbuilding and repairs, Admiralty ; **C. R. King,** chairman, East Midlands Electricity Board ; **G. J. S. Little, G.M.,** assistant engineer-in-chief, General Post Office ; **A. G. B. Owen,** joint managing director, Rubery, Owen and Co., Ltd., Birmingham ; **G. D. Smith,** managing director, Bush Radio, Ltd. ; **Captain G. Villar, R.N.(ret.), M.Inst.N.A.,** general manager Southampton works and director, John I. Thornycroft and Co., Ltd. ; **F. W. G. White,** chief executive officer, Scientific and Industrial Research Organisation, Australia ; **M. D. N. Wyatt,** chairman, Airwork, Ltd.

O.B.E. **T. H. Baines,** deputy director of radio equipment (production) Admiralty ; **J. Begbie,** superintendent engineer, Marine Department, Nigeria ; **A. D. M. Brown,** chief engineer, Iraq State Railways ; **H. Brown,** superintendent mechanical and electrical engineer, Air Ministry ; **J. Chamberlain,** chief engineer, Aiton & Co., Ltd., Derby ; **E. J. Cowles,** principal, Ministry of Materials ; **R. K. Cushing,** principal scientific officer, Ministry of Supply ; **W. Langford,** manager for France, of Associated British Machine Tool Makers Ltd. ; **J. H. McCuaig,** shipyard manager, Harland and Wolff, Ltd. ; **T. W. McCullough,** deputy chief inspector of factories, Ministry of Labour and National Service ; **A. Marsh,** director, National Smoke Abatement Society ; **F. V. Mills,** chief executive officer, Ministry of Transport and Civil Aviation ; **A. S. Mitson,** assistant director, electronics production, Ministry of Supply ; **R. A. Moir, M.C.,** chief telephone engineer, Standard Telephones and Cables, Ltd. ; **P. E. Montagnon,** senior principal scientific Officer, Ministry of Fuel and Power ; **J. Mould,** deputy chairman, East Midlands Electricity Board ; **W. C. Muirhead,** special director, English Steel Corporation, Ltd., Sheffield ; **A. J. Nicholas,** director and general manager, South Wales Switchgear, Ltd. ; **A. J. Perkins,** superintendent, Royal Ordnance Factory, Cardiff ; **T. G. Poppy,** controller, Standards Department, Board of Trade ; **M. J. L. Pulling,** senior superintendent engineer (television), British Broadcasting Corporation ; **W. H. Purdie,** engineering director, William Doxford and Sons, Ltd. Sunderland ; **B. A. Renton,** principal, Ministry of Materials ; **A. P. Ruddy,** general manager, High Speed Alloys Mining Co., Ltd., Burma ; **H. F. H. Shields,** managing and technical director, British Ropeway Engineering Co., Ltd. ; **Commander (E) D. P. Sparham, R.N. ; R. T. Stevens, M.B.E.,** director, electricity and telephones, Mauritius ; **J. M. Stewart,** technical manager, Ulster Steamship Co., Ltd., Belfast ; **W. G. Woodhead,** general manager, English Coaling Co., Port Said.

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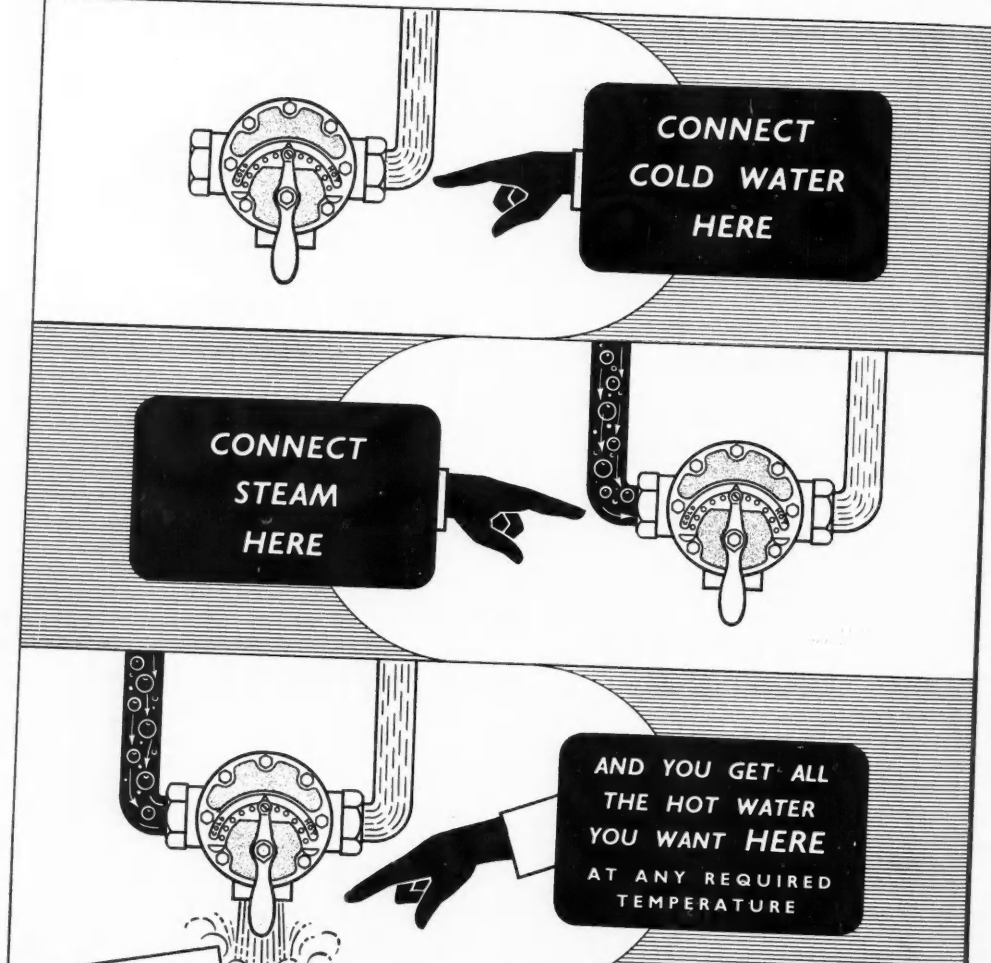

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PERSONAL

Lord Bennett of Edgbaston, C.B.E., has been succeeded by **Mr. Tom Williamson, C.B.E.,** as chairman of the British Productivity Council, 21 Tothill Street, London, S.W.1. Lord Bennett, however, will remain a member of the Council. **Sir Ewart Smith** has been appointed deputy chairman of the Council, in succession to **Sir Lincoln Evans, C.B.E.,** who earlier last year had been appointed vice-chairman of the Iron and Steel Board.

Sir Harry Brown, C.M.G., M.B.E., M.I.E.E., full-time chairman of the British General Electric Co. Pty. Ltd., Magnet House, 104/14 Clarence Street, Sydney, Australia, has resigned at the age of 75. **Mr. T. E. Morgan,** managing director, has been appointed chairman and managing director of the Australian company. **Mr. A. T. Bridge, Mr. R. J. Darton** and **Mr. C. Drabble** have been appointed directors.

Mr. E. J. Bradley, G.I.P.E., has been appointed works manager of Welding Technical Services Ltd., Birmingham.

Mr. J. B. Bryce has been appointed chief marine engineer of the Vacuum Oil Co. Ltd., in succession to **Mr. G. M. McGavin,** who is taking up special duties for the Company. **Mr. R. O. Keyworth** has been appointed Liverpool marine branch manager, in succession to **Mr. Bryce.**

Mr. C. J. Buckley, vice president of The Institute of Civil Engineers of Ireland, has been appointed chief engineer to the Dublin Port and Docks Board, Dublin.

Major-General C. A. L. Dunphie, C.B., C.B.E., D.S.O., of Vickers-Armstrong Ltd., **Mr. J. W. Platt,** of Anglo-Saxon Petroleum Co. Ltd., and **Mr. W. F. Wackrill, O.B.E.,** of Esso Transportation Co. Ltd., have been elected members of the General Committee of Lloyd's Register of Shipping, 71 Fenchurch Street, London, E.C.3.

Mr. E. F. Farrington has been appointed assistant to the chief engineer for duties in connection with capital expenditure schemes and developments of the Appleby-Frodingham Steel Co. Ltd., Scunthorpe. **Mr. R. B. Atkin** has been appointed senior civil engineer for maintenance.

Mr. H. Faulkner, C.M.G., B.Sc., M.I.E.E., F.I.R.E., has been appointed to the office of director of the Telecommunication Engineering and Manufacturing Association. Mr. Faulkner has had a lifelong connection with Telecommunication, having been for 40 years with the British Post Office, from which he recently retired after holding the rank of deputy engineer-in-chief.

Mr. H. P. Forder has been appointed deputy general manager of Samuel Fox & Co. Ltd., Stocksbridge. **Mr. R. J. Bavister** has been appointed commercial manager, **Mr. J. H. Goodlad,** deputy for **Mr. Bavister, Mr. A. Grayson,** supplies manager, **Mr. J. Mason,** buyer, and **Mr. G. J. Cummings,** education officer.

Mr. J. G. Fraser, C.A., has been appointed secretary to George Ellison Ltd. and their associated companies, Tufnol Ltd. and Alfred Ellison Ltd., Perry Barr, Birmingham 22 B. He succeeds Mr. R. Sawyer who retired after 42 years of service.

Mr. A. J. Haslam has joined the laboratory staff of the Radiant Metal Finishing Co. Ltd., Wellchrome Works, Shepherdess Walk, London, N.1.

Mr. Philip Jones has been appointed press and publicity officer of the Exports Credit Guarantee Department, 9 Clements Lane, London, E.C.4.

Mr. C. E. King has retired from his position of director of engineering of Vauxhall Motors Ltd. owing to ill health, but will continue to serve as an engineering consultant to the company.

Mr. G. H. Latham, chairman and managing director of the Whitehead Iron and Steel Co. Ltd., has been appointed President of the British Iron and Steel Federation, Steel House, Tothill Street, London, S.W.1, in succession to **Sir Ellis Hunter. Mr. A. G. Stewart** has been appointed president elect of the Federation.

Mr. F. D. Langley has been appointed sales manager, and **Mr. W. L. Beckett,** London area sales manager, of the National Gas and Oil Engine Co. Ltd., both with offices at Duke's Court, 32 Duke Street, London, S.W.1. Tel. No. WHItehall 6177. Mr. Langley has also been appointed director of National Oil Engines (Export) Ltd. **Mr. J. A. Barker** has been appointed commercial manager at the Head Office of the company at Wellington Works, Ashton-under-Lyne.

Mr. A. Lloyd has been appointed general works manager, **Mr. G. J. Taylor,** manager, and **Mr. P. Smith,** sales manager of the Thermosetting Division of Bakelite Ltd., Tyseley, Birmingham.

Mr. C. E. Tofts, has been made sales manager for laminated materials, **Mr. R. Hulse,** works manager, and **Mr. A. Tonks,** manager of moulding material production.

Mr. Donald McGregor has been appointed superintendent of the washing machine motor production line, **Mr. Norman McIntosh Hemphill,** chief plant engineer, and **Mr. Ian McGregor,** education and training officer, of Hoover (Electric Motors) Ltd., Cambuslang, Lanarkshire.

Lieut.-General Sir Frederick Morgan, K.C.B., who has been Controller of Atomic Energy since 1951, has been appointed by the Minister of Supply to be Controller of Atomic Weapons.

Mr. K. Paterson, director and chief engineer, will take up appointment, on April 1st, as general manager of The United Steel Structural Co. Ltd., Sheffield 10, of which company **Mr. H. Saunders** will be commercial manager and director. **Mr. L. Gaskell** will become chief engineer, **Mr. W. E. Smith** chief electrical engineer, and **Mr. D. R. M. Nisbet** deputy chief electrical engineer.

Mr. L. W. H. Rea, general manager, and **Mr. W. Smith,** works manager, have been elected to the Board of Edwin Danks & Co. (Oldbury) Ltd.

Mr. J. S. Skinner has been appointed managing director and **Mr. George McLean** a director of Remington Rand Ltd., Commonwealth House, New Oxford Street, London, W.C.1. **Mr. S. D. Parker** has been elected chairman of the Board.

Mr. Z. Stokowiec, A.M.I.Mech.E., F.I.M., has been appointed bronze foundry manager of Sheepbridge Engineering Ltd., Chesterfield.

Mr. R. Tate, of the Defence Research Board of Canada, has taken up a position as metallurgist with Trans-Canada Air Lines, Winnipeg, Canada.

Mr. P. Tatlow has been appointed sales manager of the general engineering department of Air Control Installations Ltd., Ruislip, Middlesex. Mr. Tatlow was formerly with A.C. Cossor Ltd., as chief mechanical engineer of the research division, and prior to that was chief designer of Rotax Ltd. He commenced his career with Rolls Royce Ltd.

Mr. W. E. P. Johnson, A.F.C., A.F.R.Ae.S., C.P.A., has relinquished the joint managing directorship of Power Jets (Research and Development) Ltd., but will continue in advisory capacity. **Mr. T. G. Hicks, M.A., C.P.A.,** joint managing director, has been appointed managing director.

Mr. Frank Thompson-Schwab, chairman, **Sir Alexander Dunbar,** deputy chairman, and **Mr. Hugh Quennell,** director of Darwins Ltd., Sheffield, have joined the Board of Sheffield Forge and Rolling Mills Co. Ltd., the entire share capital of which has been acquired by Darwins Ltd.

Mr. E. S. Waddington, F.S.E., M.Inst.W., A.I.E.E., has been appointed honorary treasurer of the Society of Engineers.

Mr. G. S. Webley, A.M.I.P.E., has been appointed director and general manager of the Cape Engineering Co. Ltd., Warwick.

Mr. N. Yarworth has taken up an appointment with Metals and Controls Corp., Attleboro, Mass., U.S.A.

BUSINESS NOTES

Aylesbury Turned Parts (True Screws) Ltd., Brittania Street, Aylesbury, Bucks, have been appointed Agents for the "Helios" precision measuring instruments.

Hattersley (Ormskirk) Ltd., Ormskirk, Lancashire, have acquired 75 per cent of the share capital of Beck & Co. (Meters) Ltd.

The Staveley Coal and Iron Co. Ltd., Hollingwood, Chesterfield, have acquired 75 per cent of the share capital of Standard Machine & Tool Co. Ltd., Windsor, Ontario, Canada. Considerable expansion of the plant is contemplated. **James Archdale & Co. Ltd.,** Birmingham 16, will exchange technical information with **Standard Machine & Tool Co. Ltd.**

The Ackton Hall Colliery Co. Ltd., Pontefract, Yorkshire, have acquired controlling interest in the Schultz Die Casting Co. of Canada Ltd., Wallaceburg, Ontario, Canada.

Permali Ltd., Bristol Road, Gloucester, have announced 5 per cent reduction of all prices for Permali products, excluding embodied metal parts, as from January 1, 1954. This reduction will be applied to all orders already accepted and delivered after that date.

Comparison of the price of Permali with that of all materials used in the electrical industry and covered by the Board of Trade Price Index is most favourable for Permali. The current figure for Permali, based on the 1949 datum used in the Index, is 108·9, which compares with the December Index figure of 157 for all materials.

The British Thomson-Houston Co. Ltd., announce that their Middlesbrough office has been installed in new premises at Prudential Chambers, 27 Albert Road, Middlesbrough. Tel. No.: 2476.

An Ultra-sonic Apparatus for collecting dust extracted from industrial plants is now manufactured at the Wilhelm Pieck Works in Hungary. It will be used in the coal classifying and cleansing department of the Varpalota coal mines for trapping and compressing 100 tons of dust per day.

The Saturn Group of Companies, in order to promote greater efficiency, has decided to concentrate the handling and marketing of industrial gases in one company as from 1st January, 1954.

The name of the parent company, Saturn Oxygen Company Limited, has been changed to **Saturn Industrial Gases Limited,** as it was felt that the former name was not fully descriptive of its new functions, and it has absorbed the assets of its four subsidiary companies, namely :—

British Cutting Gases Ltd., New Process Gases Ltd.,
Autogenous Gases Ltd., Augas Northern Ltd.

While some familiar names may disappear, this arrangement will involve no change in the continuity of management, and the Group's endeavour to render a high standard of service to industry will be continued by Saturn Industrial Gases Ltd., together with its subsidiary company, Rainville Engineering Co. Ltd., from their branches

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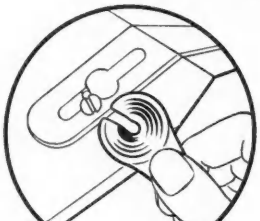

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For single or twin 80 watt 5ft. Fluorescent lamps.

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in London, Lymington, Birmingham, Sheffield, Manchester, Thornaby-on-Tees, Sunderland and Glasgow.

The Head Office will remain at Downshire House, Roehampton Lane, London, S.W.15, and the Registered Office at 50 Gresham Street, London, E.C.2.

Mr. Patrick Johnson, who recently resigned from Power Jets (Research & Development) Ltd. to extend the scope of his activities in technological consultancy, has been appointed to develop the European interests of Solar Aircraft Company, of San Diego, California, U.S.A.

In this appointment, he will maintain his connection with gas turbines, which originated in his early association with Sir Frank Whittle, as Solar Aircraft Co. are also manufacturers of gas turbines and their components. Mr. Johnson, who will remain free to serve the various other organisations and committees of which he is a member, and to be available as an adviser to Power Jets and others, is leaving for the U.S.A. at the end of January for an extensive tour. He will open his London Office on his return in the Spring. Until then, he may be reached through his home address : 46 Well Walk, N.W.3. Telephone : HAMpstead 1664.

The Society of British Aircraft Constructors announces that the 1954 SBAC Flying Display and Exhibition will be held from Tuesday September 7th to Sunday September 12th inclusive. There will be a Technicians Preview on Monday September 6th.

The Display will be held in Farnborough, Hampshire.

Stanley Howard Ltd., 75/76 Exchange Buildings, Stephenson Place, Birmingham 2, has been appointed Sole Agent for the sale of Scrivener automatic rotary horizontal surface grinding machines.

Thos. Firth & John Brown Ltd., Atlas Works, Sheffield 4, announce that the new address of their Cardiff Office is now 46 Park Place, Cardiff. Telephone : 27922.

The Cone Automatic Machine Company (Great Britain) Limited has been formed as a subsidiary of the Cone Automatic Machine, Inc., Windsor, Vermont, U.S.A. to inaugurate and be responsible for a manufacturing programme for their range of Automatic Bar Machines. Temporary premises have been acquired at Solihull Chambers, 14 High Street, Solihull, Birmingham.

The directors are Mr. H. P. Chaplin, Mr. J. A. Gerard, President and Vice President respectively of the parent company, and Mr. Louis Carter who has resigned his directorships of the Churchill Group of companies to take up the managing directorship of the new company.

The range of machines will be manufactured for the home and export markets.

Charles Churchill & Co. Ltd. who have acted as agents for the Cone Automatic Machine Co. for many years will continue in this capacity in Great Britain.

Sheepbridge Engineering Limited announce that by agreement with the United States Pipe and Foundry Co., Special Products Division, Burlington, New Jersey, the special method developed by the American firm for making long cast cylinders and tubes, can be employed by two Sheepbridge subsidiaries—Sheepbridge Steel Castings Ltd., Sutton-in-Ashfield, Notts., and Sheepbridge Stokes Ltd., of Chesterfield.

A prominent feature of this new horizontal rotation process is the use of a special refractory spray round the walls of the mould that induces the casting metal to flow evenly throughout its length, thereby eliminating a principal difficulty in normal British practice.

The intention of Sheepbridge Steel Castings Ltd. to spin cast piping in high alloy steels and nickel base alloys by this process has aroused considerable interest in the chemical industry where long piping in special alloys is difficult to produce by normal methods.

Heat-resisting and corrosion resisting steel alloys will also be spun in long castings by this new process for ultimate use as rollers in heat treatment furnaces, runout-rolls for steel mills etc.

Experimental 10 foot long iron cylinders of 8 in. diameter, have already been successfully cast by this new " Burlington " process at the Chesterfield Works of Sheepbridge Stokes Ltd.

Corrosion of Iron and Steel. Methods of protecting iron and steel against corrosion will be demonstrated to the public in the Great Hall, Battersea Polytechnic, from 10.0 a.m. to 4.30 p.m. on Friday, January 22nd. The exhibition will be on view during the previous day to members of the Corrosion Group of the Society of Chemical Industry, by whom it is being organized.

Some 30 exhibits will demonstrate the most important methods and processes for the prevention of corrosion of iron and steel in five main sections :

Effect of Design
Treatment of the Corrosive Medium
Cathodic Protection
Protective Coatings
Tests and Methods of Testing.

Although many individual firms are participating, this is not a trade exhibition, but a demonstration of protective processes. Admission is free, and no tickets will be necessary.

It is proposed to establish at the **National College of Horology and Instrument Technology,** St. John Street, London, E.C.1, commencing in September, 1954, courses in the technology of tooling as it applies to the horological, instrument and light engineering industries.

This decision has been reached after discussions with engineers and executives in industry who have stated that the design and manufacture of accurate and economical tooling is one of the most vital factors in production. The scheme has also been discussed with the **Gauge and Tool Makers Association.**

Two full time day courses have been drafted and are approved in principle by the Board of Governors and the Ministry of Education. These courses are suitable for apprentices and others who have reached certain steges in a National Certificate course in Mechanical or Production Engineering.

" Wiggin Nickel Alloys " No. 23 reviews work carried out on crop drying by electricity, a major development in farming. Types of industrial heating elements, ultra violet and infra-red ray radiation, filtration, incubation, cathode ray tube seals, temperature control, electrical upsetting and the introduction of Nimoply are other subjects dealt with. Copies of this journal may be obtained free of charge by writing to Henry Wiggin & Co. Ltd., Thames House, Millbank, London, S.W.1.

The Edward Curran Companies. A most interesting record of fifty years of achievement, foresight, and versatility is contained in an 88-page book, recently issued by the Curran Companies of Cardiff. The book, which is well illustrated and produced, traces the development of these Companies from Edward Curran's " Incandescent Arch " Furnace, first installed at the Mountstuart Dry Docks, Cardiff, in 1909, to their present multifarious activities, involving a considerable knowledge of the casting, rolling, fabricating, forming, heat treatment, cleaning, and coating of metal, together with the design and construction of plant and machinery required for these processes.

To-day, the Edward Curran Companies not only design and build furnaces, but metal surface treatment plants and agricultural machinery as well ; they are manufacturers of steel castings, earth-moving equipment, and enamelled ware ; they are electrical and radio wholesalers and distributors ; and they are oil importers, blenders, and distributors.

The book outlines these activities, together with several others, including the manufacture of cartridge-cases and flails for tanks. Not the least interesting thing about this publication is the excellent collection of photographs and sketches of their activities during and after the First World War.

Research at Hadfields. Research activities at Hadfields Limited, Sheffield, are detailed in a superbly conceived and illustrated 80-page publication, recently received. Actually, these activities date from the Company's earliest days, starting with the work of Sir Robert Hadfield, Bart., F.R.S., who was one of the foremost metallurgists of his generation, and who took out the first patent for manganese steel in 1883.

In those early days, the centralised research department, now such a familiar feature of industry, was unknown. Research was carried out in any department of the works where facilities could be found. In 1947, the present Central Research Building became available for the concentration of research. To-day, laboratories cover three floors of this building. An experimental foundry occupies a building of its own, while the radiographic laboratory adjoins the foundry.

Whilst much new equipment was introduced when the centralised research building was first occupied, constant additions are always necessary to keep pace with advancing scientific practices. Many of the instruments used in various branches of research, together with details of the results obtained, are described and illustrated in this interesting publication.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

DRAUGHTSMAN REQUIRED with a good general knowledge of the design of special process machines and plant. Practical experience essential. Good working conditions. Pension scheme. Write for interview giving particulars of training and experience to The Assistant Secretary, **The Micanite & Insulators Co. Ltd.,** Empire Works, Blackhorse Lane, E.17.

YOUNG ENGINEERS. The Hymatic Engineering Co. Ltd., require young engineers with degree in Mechanical Engineering or Physics or with H.N.C., for interesting and instructive work in development of mechanical, electrical and fluid mechanisms for aircraft and industrial applications. Some industrial experience desirable but not essential. Pension Scheme. Excellent conditions. Apply with full details to Technical Manager.

TO LET

MODERN OFFICE BUILDING at Victoria to let with immediate vacant possession of 11,500 sq. ft. on three floors. Possession of further 7,600 sq. ft. in five years. Rent required equivalent to 18/- per sq. ft. exclusive. For full particulars, write Box LS 154.

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GRAVITY DIES, designed, manufactured and proved. **R. E. Ormerod Ltd.,** Ednall Lane, Bromsgrove.

RECONDITIONED EX-ARMY HUTS, and manufactured buildings. Timber, Asbestos, Nissen Type, Hall Type, etc. All sizes and prices. Write, call or telephone—**Universal Supplies (Belvedere) Ltd.,** Dept. 50 Crabtree Manorway, Belvedere, Kent. Tel. : ERITH 2948.

WANTED.—Copies of the March, 1953 issue of " The Engineers' Digest " urgently required. Also Jan., 1949, June, 1950, and Dec., 1951, issues at 3/6 per copy.—Subscription Dept., 120, Wigmore Street, London, W.1.

BOOKS RECEIVED

FBI Register of British Manufacturers, 1954. 26th Edition, 952 pp.; published November, 1953, for the Federation of British Industries by Kelly's Directories Limited, and Iliffe and Sons Limited, Dorset House, Stamford Street, London, S.E.1. Price: 42/-.

This standard export reference book of British industry is the only authorised directory of the Federation of British Industries, the largest and most influential association of British manufacturers, and is compiled by the publishers in close collaboration with the F.B.I. As such, it is an invaluable aid in finding reliable sources of supply by importers, buyers, trade commissioners, chambers of commerce, commercial attachés, reference libraries, etc. throughout the world. The introductory information and detailed instructions on the use of the Register are translated into French and Spanish.

The Register contains seven sections, each section having a reinforced index card for easy reference. A buyers' guide classifies over 6500 F.B.I. member firms under more than 5000 alphabetically arranged trade headings, while full details of all these firms are given in a comprehensive alphabetical directory. Other sections provide useful information on trade associations, proprietary names, trademarks, etc.

Manual of Mechanical Power Transmission. Third Edition, 1953. 632 pp., 381 illustrations. Publishers: Trade & Technical Press Ltd., 65-66, Chancery Lane, London, W.C.2. Price: 51/-.

Every plant engineer should possess in some handy form the essential information which will enable him to deal promptly with everyday problems arising in connection with the efficient operation of transmission equipment. The aim of this volume is to achieve that purpose.

Each section has been carefully revised, new chapters on recent developments have been added, many new diagrams and tables have been incorporated, and, where necessary, existing material has been revised. Also, the opportunity has been taken to increase the overall size of the pages, thereby permitting the use of a larger and more readable type face.

Sections are devoted to the subject of bearings, belts and belt joining, chain drives, compressed air, couplings and clutches, gears, hydraulic transmissions, pulleys, rope drives, V-belts and V-ropes, and shafting. In addition, there is a section devoted to flywheels, foundations and machinery fixings, centrifugal force and kinetic energy, relationship of horse power to torque, and miscellaneous engineering tables.

Vermuyden and the Fens. By L. E. Harris. 168 pp., 9 illustrations. Publishers: Cleaver-Hume Press Ltd., 42a, South Audley Street, London, W.1. Price: 21/-.

This is the first fully documented study of the work of Sir Cornelius Vermuyden, the naturalised Dutchman who, in association with the Earls of Bedford, undertook in the mid-17th century the drainage and reclamation of the major part of the now rich and fertile English fenlands. It thus illuminates a corner of English economic history, and should be of great interest to geographers, agriculturists, and all those concerned with the history of engineering.

Three hundred years ago, the work on the Great Level was completed, and this book is all the more apt at a time when it is proposed to spend large sums on a flood-prevention scheme, some features of which are remarkably similar to the ideas of Vermuyden.

What is believed to be a contemporary portrait of Vermuyden is reproduced as a frontispiece. The other illustrations, from old maps and documents, greatly enhance this volume, which should appeal to collectors of many kinds.

The Aircraft Engineer's Handbook. *No. 1:—Airframe Structure and Controls, Flying Instruments and Equipment.* By W. J. C. Speller, A.F.R.Ae.S. 302 pp., 81 illustrations. Publishers: Sir Isaac Pitman & Sons Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price: 30/-.

This volume is the first of a new series designed for aircraft engineers qualifying for "M" (Maintenance) Licences, as laid down by the Air Registration Board in the British Civil Airworthiness Requirements (Section L, Licensing).

It covers the Category "A" Licence and, as such, deals comprehensively with the complete airframe, including the hydraulic system, brakes and wheels, heating, fire-fighting, and de-icing equipment, instruments, automatic pilots, etc.

This book should be of great service to Air Forces, to the staffs and students of schools, colleges, universities, and training institutions, and to all personnel engaged in the inspection and maintenance of aircraft.

How to Use Signal and Sweep Generators. By J. Richard Johnson. 144 pp., 102 illustrations. Publishers: John F. Rider Publisher, Inc., 480, Canal Street, New York 13, U.S.A. Price: $2.10.

While much has been written about the theoretical aspects of signal and sweep generators, there has been a scarcity of information on their actual manipulation and applications to practical problems.

This book includes sufficient information on the fundamentals of generator operation to clarify the purpose of all practical steps detailed. Otherwise, theoretical discussions are avoided in favour of practical instruction, while the book is written is such a way that the reader requires only a basic knowledge of electricity, radio, and electronics.

Specific information is given on the types of equipment available and their basic principles of operation; the purpose and location of controls and adjustments; and the setting up, adjustment, and maintenance of generators for various applications.

LATEST INDUSTRIAL LITERATURE

1. Steel-Framed Buildings. Details are given in a 4-page pamphlet of a range of steel-framed buildings. The span of these buildings is from 30 to 60 ft, and their length can be any multiple of 12 ft 6 in.

These buildings are designed to allow for two or more spans to be joined together to increase the width, as required. Also, lean-to extensions of 15 or 20 ft in width may be added to any of the standard spans. Steel windows, 6 ft 6 in. × 4 ft high, with top-hung ventilators, can be supplied for fixing in side walls or gable ends.

2. Aluminium Alloys. The mechanical and physical properties of a range of light alloys, made from aluminium and magnesium, are detailed in a neat, illustrated 8-page booklet. Weight reduction and good durability are features of these alloys, but their diversity of properties and finishes, and ease of working greatly extend their scope of application.

3. Variable-Pitch Marine Propellers. A well-presented, 28-page brochure describes and illustrates variable-pitch propellers fitted to a wide range of marine craft, including tugs, firefloats, submarines, motor torpedo-boats, and air-sea rescue launches, powered by petrol, diesel, steam, and gas turbine engines, ranging from 15 to over 6000 hp.

Performance curves, illustrating the advantages to be derived from the use of variable pitch propellers, are included.

4. Fittings for "Alkathene" Tubing. The increasing use of "Alkathene" tubing for cold water distribution lines and for industrial and chemical plant has resulted in the need for a quick and reliable method of jointing.

An efficient range of fittings for joining this type of tubing is described in a 12-page booklet. These fittings are made from hot-stampings or hard-castings in brass. The action of tightening the coupling nut on to the screwed exterior of the fitting body compresses a specially designed annealed brass ring on to the tubing, thereby gripping it securely.

5. Impervious Carbon and Graphite Material. A 6-page brochure describes an impervious carbon and graphite material specially intended for the construction of plant handling corrosive fluids. Outstanding properties of this material include low thermal reversible expansion; wide range of resistance to chemical attack; good mechanical strength; high resistance to thermal shock; good electrical conductivity; and self-lubrication and resistance to wear.

Four main types of heat-exchanger, made from this material, are described in the brochure. These are the Shell-and-Tube (or Tube Bundle), the Plate Heater, the Cascade Cooler, and the Bayonet Heater, respectively.

6. Pneumatic Equipment. A well-presented and illustrated 12-page booklet describes a comprehensive range of pneumatic equipment for industrial purposes, including air hydraulic feed units, hydro-checks, solenoid and diaphragm-operated valves, impact cylinders, air service units, and integral valve/cylinder units.

A supplementary leaflet gives the prices of these and other items, together with a shortened price-list of solderless pipe fittings.

7. Water Purification Equipment. Chlorine is universally recognised as a most efficient bactericide. Details of a complete range of equipment for use in chlorination plants are given in a 4-page brochure. The range includes a variety of automatic and portable chlorinators, ammoniators, reagent feeders, high-capacity direct feed panel units, chlorine residual recorders, hydraulic solution feeders, programme clocks, and master chlorinators.

8. Tube Cutting and Screwing Machines. A pamphlet describes and illustrates two models of tube cutting and screwing machines, one for tubes from ¼ to 2 in. in diameter, and the other for tubes from ½ to 4 in. in diameter.

These machines are fitted with low-power motors in all voltages. If desired, petrol motor and compressed air driven models can be supplied.

9. Self-Cleaning Strainer. Descriptions and specifications of a wide range of self-cleaning strainers are given in a 12-page brochure. These strainers, which embody a novel cleaning principle, are of simple and robust design, and are so constructed that they offer a minimum resistance to flow and do not become choked.

In the larger sizes, jacketed strainers for heating or cooling the liquid are available. These latter strainers also lend themselves for use in the concentration of solids.

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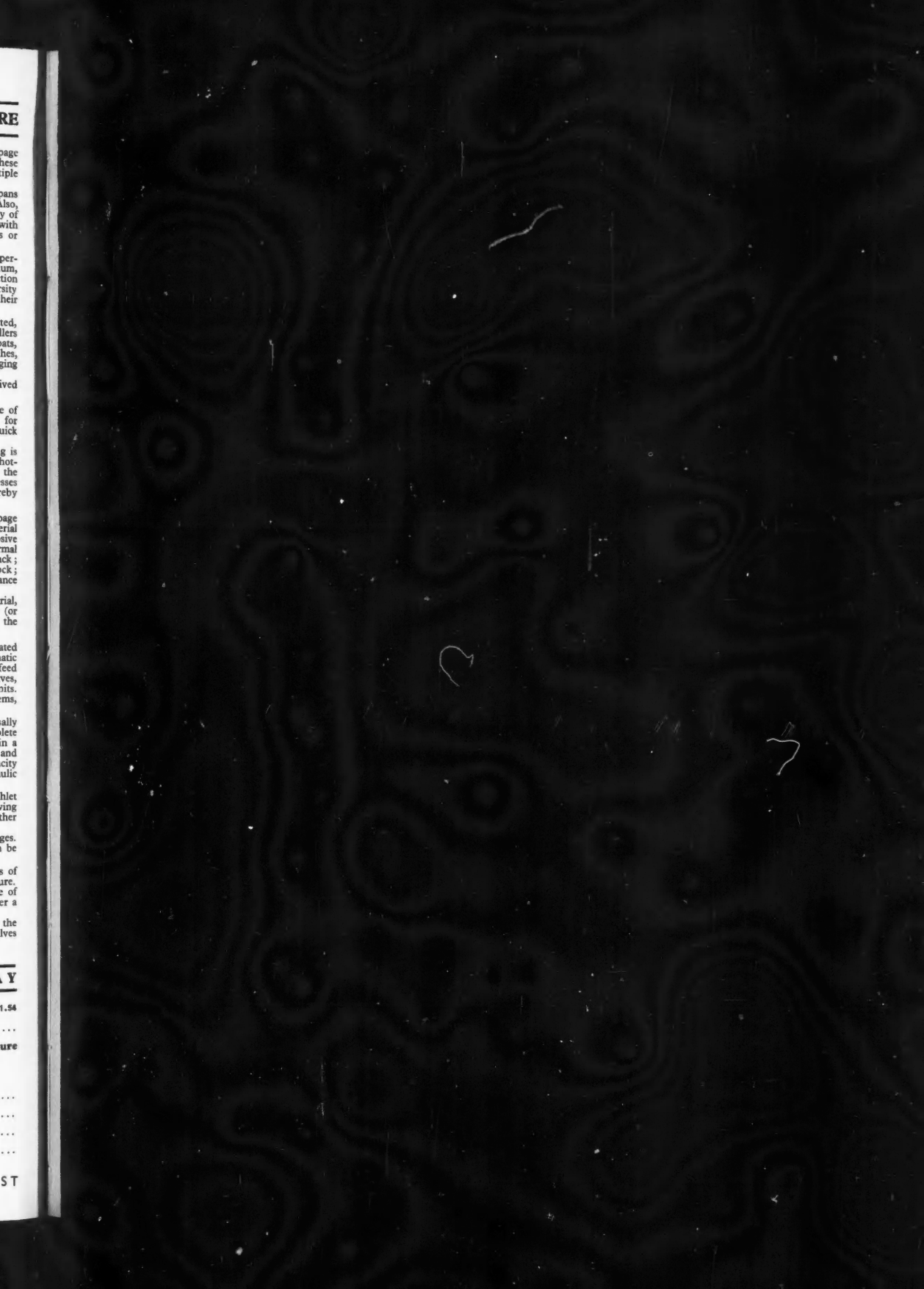

THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *NEW HIGH-STRENGTH ALLOY*

It is reported that the search for a nickel-free steel for high-strength wire has resulted in the development of a new type of steel with remarkable qualities. The problem with which the investigators were faced was to evolve a wire material which would contain less chromium and nickel than comparable materials, but would have the strength, flexibility, and the magnetic and electrical properties of the material to be replaced. A considerable number of alloys was developed and tried. One of these alloys, when drawn into wire of 0·0015 in. diameter, was found to have a tensile strength of 292,500 psi and to be non-magnetic, as required. Another alloy, when drawn into wire of the same diameter, was rated at 300,000 psi tensile strength. Beyond the laboratory stage, a 225-lb melt of one alloy was passed through a commercial wire mill and was processed according to the standard procedure developed for stainless steel. With a 93% reduction in area the wire was found to have a tensile strength of 300,000 psi. This material had the following analysis: 0·10% carbon, 10·7% chromium, 16·0% manganese, 0·9% silicon, 2·0% copper, and 0·15% nitrogen. The nitrogen was added as high-nitrogen ferro-chromium. It is stated that the percentage ranges of steel of this type should range as follows, although further development would appear to be indicated: 0·3 to 1·3% silicon, 0·08 to 0·15% carbon, 9·0 to 11·0% chromium, 14·5 to 18·5% manganese, 1·8 to 2·2% copper, and 0·08 to 0·15% nitrogen. Steels of this type are recommended for applications requiring good workability, moderate corrosion resistance, relatively low electrical conductivity, and non-magnetic properties.

● *PRESSURE-SENSITIVE TAPE*

The fluorocarbons, which constitute a relatively recent addition to the plastics family, are of considerable interest to manufacturers in view of their outstanding properties. Notable among the latter are their excellent mechanical stability, their high resistance to most corrosive materials, and their dielectric strength. The combination of these properties makes the fluorocarbons most desirable for use in the chemical and electrical industries and in many others, where insulation and protection against corrosion are important factors. Fluorocarbons are now available in the form of a pressure-sensitive tape, which should prove particularly useful in electrical applications, owing to its excellent insulating properties. This new tape can be applied like any adhesive tape, yet it retains all the advantages inherent in fluorocarbon materials. The tape consists of a fluorocarbon plastic, to which a silicone adhesive is bonded by a special process. The adhesion of the tape to various metal surfaces is reported to be some 32 oz per inch, and the silicone adhesive is said to remain strong and tacky over a range of temperatures from about +300° F to — 65° F. According to the manufacturers, the process by which the adhesive is bonded to the tape does not adversely affect the fluorocarbon polymer, so that the finished tape retains unimpaired all the basic physical, chemical, and electrical properties of the material. Tape of this kind is being manufactured in widths up to 24 inches. The new tape may be used for wrapping ends and splices in Teflon-insulated wires and cables, and for providing non-adhesive surfaces in containers or on tables. Small containers can be lined with a single layer of pressure-sensitive tape, or the adhesive can be applied to shaped or curved fluorocarbon surfaces.

● *NUCLEAR STORAGE BATTERIES*

Generation of electrical energy, by collecting the beta particles emitted from a radioactive source insulated from the source by a solid dielectric, has been found feasible with polystyrene as the insulator. Batteries using a strontium-90 source, and providing up to 7000 V charging potential at 40 $\mu\mu$A, have been produced. These batteries are smaller, lighter, and less expensive to operate than chemical batteries, and have the additional advantages of greater reliability and a life of up to 25 years under extreme operating conditions. They represent the first instance of atomic energy being converted directly into electrical energy for commercial use, although, in their original form, they can be used only for applications requiring small currents, such as ionisation chambers. It is reported, however, that an adaptation, incorporating a silicon transistor and capable of releasing sufficient energy to operate a telephone receiver, is now available. It is claimed that the new battery may well be the first step in a development leading to the supply of " packaged " electricity for domestic and industrial purposes.

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FACTORIES AT ST. HELENS, LANCS., AND POSSILPARK, GLASGOW

● *DETERMINATION OF COOLING POWER OF QUENCHING BATHS*

It is common knowledge that the properties of a hardened steel vary according to the speed at which it has been quenched, and that, other conditions being equal, the quenching speed depends upon the characteristics of the quenching bath. For each quenching bath, therefore, the quantity of heat which the bath can remove from the workpiece under standard conditions per unit of time at various temperatures should be investigated. For this purpose the " cooling power " of each quenching bath is to be considered, and this cooling power can be defined by the cooling speed against temperature curve under standard conditions. A recent invention relates to an apparatus which is claimed to simplify considerably the determination of the cooling power. This apparatus contains a device for simultaneously determining temperature against time and the cooling speed against time diagram of a body plunged into the quenching bath under investigation. The invention is based upon the fact that the derivative with respect to time of the temperature against time curve is the cooling speed against time curve. From these two curves a third curve, namely, cooling speed against temperature, can be derived, which defines the " cooling power " of the quenching bath investigated. The actual apparatus permits automatic determination of the cooling speed against temperature curve. In the apparatus a silver ball containing a thermocouple is heated to a given temperature and then plunged into the bath. The thermocouple then actuates a first amplifier and a second amplifier with a derivative stage, so that temperature against time and cooling speed against time are simultaneously obtained, and provision is made for automatically plotting the cooling speed against temperature curve.

● *MEASUREMENT OF DIELECTRIC DISPERSION*

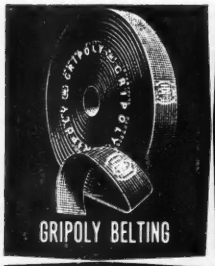
A patent specification just issued describes a new method applicable to the testing of materials used for electrical insulation, such as paper, cotton, and other fibrous materials. The insulating properties of these insulating materials are impaired by the presence in them of small amounts of moisture, and tests for moisture content can therefore serve as a guide to the condition of the material. It has been found that measurement of the dielectric dispersion of the material, i.e., the variation of the dielectric constant with the frequency of an applied sinusoidal voltage, or the duration of an applied voltage of square wave form, furnishes a particularly suitable means of assessing the moisture content of such materials. It is claimed that results have been attained in the testing of oil-impregnated papers, as used in cables and transformers, and of resin-bonded paper of the type used in bushings. The test can be quite sensitive and is absolute in the sense that completely dry materials have zero dispersion; furthermore, it may be carried out on the insulation of electrical equipment already installed. It may also be used for checking the effectiveness of the drying process during manufacture, since paper insulation is used to a considerable extent at the present time in bushings, cables, and transformers, and drying is an essential step in their manufacture. The operating principle of the apparatus employed to carry out the actual tests consists of charging the material by applying the test voltage by means of a pulse generator, and then measuring the recovery voltage, after short-circuiting for a brief time interval the electrodes used for applying the voltage to the material.

● *GLASS OF CHANGING LIGHT TRANSPARENCY*

A new type of multi-layer glass sheet of variable transparency has been developed. It may be mentioned that there already exists a type of multi-layer glass sheet which has an interlayer consisting of wax or a super-saturated solution of camphor in dilute alcohol. This interlayer becomes transparent when it is heated by means of heating filaments and it becomes opaque when the current flow through the filament is interrupted and the interlayer substance hardens. In the new type of glass, the substance contains a polymer, such as methyl polyvinyl, and is so composed that, at a predetermined temperature, the substance changes from the sol state to the gel state; these two states have, of course, widely different optical properties, the gel state being characterised by a milky appearance and the sol state by a completely transparent appearance. It is evident that the changes in temperature to which the interlayer substance reacts, instead of being effected by radiant heat, can also be effected by luminous intensity, as, for instance, sunlight. In order to make the interlayer substance more responsive to sunlight, a small quantity of a colouring agent which readily absorbs light by converting it into heat may be added. It is also possible by admixing colouring agents to produce a complete change in colour at the coagulation temperature. Furthermore, windows made of glass sheet of this type can be made opaque artificially by blowing hot air against them or by heating.

● *NEW APPLICATION OF PLASTICS*

Because of their outstanding properties, non-plasticised vinyls are now finding wide application as corrosion-resistant structural materials. The stability of this material in the presence of moisture is excellent, as is its resistance to a wide range of chemicals. Furthermore, the material is distinguished by its easy machinability and weldability. Hardness and structural rigidity of hard polyvinyl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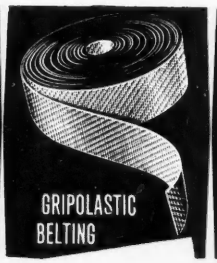
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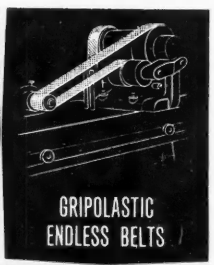
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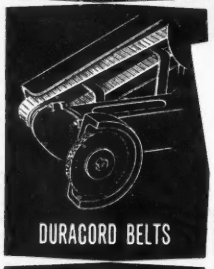
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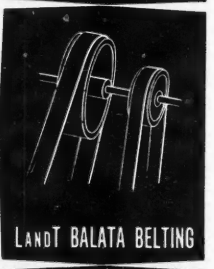
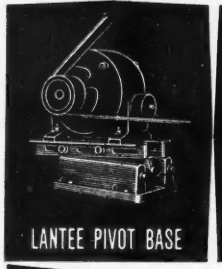
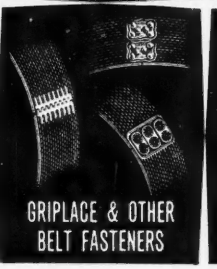
LANDT MILLERS' WEBBING

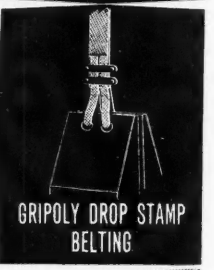
LEATHER BELTING


LANDT BALATA BELTING


LANTEE PIVOT BASE

CONVEYOR BANDS & COMPLETE CONVEYORS


GRIPLACE & OTHER BELT FASTENERS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chloride are due principally to the omission of plasticisers, which can bleed out, leaving a spongy structure. Thus, in many of their properties, non-plasticised hard vinyls surpass the " rigid " vinyls, which contain plasticisers. A temperature of 176° F is the recommended maximum temperature for the non-plasticised vinyls. A thermoplastic, hard polyvinyl chloride has good structural properties, which make possible the use of rigid assemblies without structural support other than that supplied by the plastic itself. At 160° F, the tensile strength of the material is 2900 psi, while at — 55° F it is 13,800 psi. At ordinary temperatures, hard polyvinyl chloride is unaffected by mineral acids, bases, salts, chlorides, oils, grease, petrol, and carbon tetrachloride in various concentrations. It is, however, susceptible to some organic solvents, such as aromatic and chlorinated hydrocarbons, esters, ethers, and particularly ketones. Because of its resistance to ageing and oxidation, it is suitable for many applications where oxidation is a problem. The plastic is self-extinguishing and non-toxic. Non-plasticised polyvinyl chloride is fabricated primarily by welding or machining. Sawing, drilling, cutting, shaping, planing, and milling are accomplished on conventional machine tools. Hard vinyls are, however, thermoplastic, and surface softening will occur if heat is developed too rapidly during machining.

● *AIR-TIGHT JOINTS*

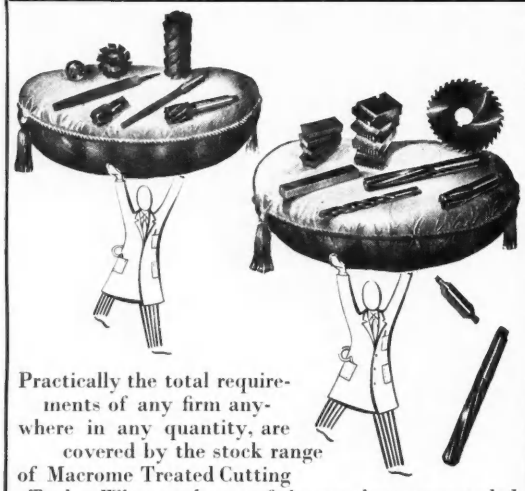
There exist many cases in which a substantially air-tight joint between mating surfaces which have to be separated from time to time should be made with a minimum of expenditure. This applies in particular to cases where the mating surfaces are of narrow width, irregular in contour, or have numerous openings for screws or bolts. In a recently patented method an adhesive cement, which may be a thermo-setting synthetic resin, is applied to one of the two surfaces. A flock material, which may be wool, cotton, rayon, or other fibre, is then deposited upon the wet cement from a suspension in air or gas by blowing on, or by passing the article through an atmosphere with the fibres or flock suspended in it. A possibly still more effective method consists in employing electrostatic attraction, which will cause the attracted fibres to stand upright on the cement-covered surface. When the cement has finally set, the deposited flock will firmly adhere to it and, owing to its softness, will form an excellent seal. After the cement has set, the surface is non-tacky and the joint may be easily broken without disturbing the flocked surface. Naturally, a joint of this type is suitable only for low-pressure air or low vacuum service; however, when these conditions are present and irregular mating surfaces are to be jointed, this ingenious method appears to have considerable utility, particularly where low cost and simplicity of fitting are of importance.

● *POWER-PRODUCING CHEMICAL-REACTION TURBINE*

What would appear to be a most significant invention of recent date relates to a process for effecting chemical reactions within the casing of a power-producing turbine, which combines the production of power from the energy available in a chemical manufacturing process. In such a process, the chemical reactions comprising a chemical process are effected under gas- or vapour-forming conditions in the casing of a gas turbine acting both as the reaction chamber of the process and as a means of generating power. Preheated reactants are injected separately into a turbine, generally at super-atmospheric pressure. The reactants are intimately mixed and chemical reactions ensue within the turbine, forming a gaseous or vaporous product. Simultaneously with the chemical reaction, the reactants and gaseous products are allowed to expand within the turbine, giving up energy in the form of mechanical work. The gaseous effluents of the reactions are recovered from the exhaust of the turbine as valuable products or for further treatment. Chemical processes suitable in this respect are preferably those involving high-pressure, high-temperature gas- or vapour-forming reactions of the exothermic type, or where the volume of the reaction products is greater than the volume of the reactants. As an example of a high-temperature, high-pressure exothermic process, the non-catalytic alkylation of hydrocarbons may be mentioned, the process conditions being some 900° to 1100° F at 2500 to 5,000 psi or 10,000 psi. Non-catalytic polymerisation of petroleum fractions can also be carried out in this manner, with process conditions of 850° to 1150° F at 1000 to 2000 psi.

● *INCREASING HEAT TRANSFER BY ELECTRICITY*

It has been found that by the use of an electrostatic field produced by electrodes connected to a high-voltage direct-current source, convection heat transfer can be substantially increased. It is claimed that, by applying an electrostatic field to a fluid while it is being heated or cooled, a continuous motion of charged particles from a surface of one polarity through the fluid to a surface of opposite polarity is effected. This, it is stated, provides a greater and more rapid heat exchange and also a more rapid equalisation of the temperature of the fluid body itself. According to the patent specification which refers to the practical applications of this discovery, a potential gradient of 1500 volts per inch is required, and increases in the rate of heat transfer of some 1100% have been observed. The inventor suggests that his method can be employed for the cooling of electric motors, transformers, and generators; also in radio transmission equipment, where it is desirable to cool the valve anodes. In gas turbines



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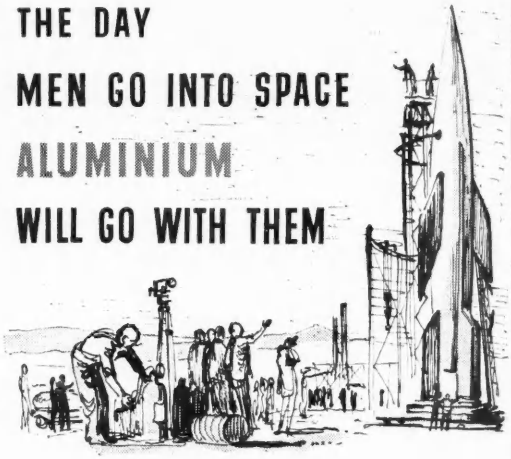

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and internal combustion engines the new method might be used to cool locally overheated parts. Other possible applications mentioned are in connection with heat exchangers in general, furnaces for normalising, annealing, or other kinds of heat treatment of steel, and cooling of plastics. The use of an electrostatic field for the purpose of increasing heat transfer is an interesting proposal and it should not be difficult to verify the claim of the inventor. However, the employment of the high voltage inferred by the stipulation of a potential gradient of 1500 volts per inch may prove an obstacle to practical application of the method in many cases.

● *NEW APPLICATION FOR SILICONES*

Recent years have witnessed a steadily growing list of uses for silicone compounds in numerous branches of industry. The latest developments are a slip clutch and a flexible coupling, which use the unusual silicone putty-like material which is plastic and free-flowing at low stress but which shatters like glass under sudden forces. The basic principle of these developments is that the putty will shear under a sudden force but will flow together again when the force is relieved. The slip clutch is designed to prevent overload and shocks, for starting heavy loads, for absorbing torsional shaft vibrations, and for delivering impulse-free power. The flexible coupling is designed to compensate for both angular and offset misalignment. The separate function of both the slip clutch and the flexible coupling can be combined in a single unit. In operation, when the driving shaft of the slip clutch starts to rotate, the initial torque shears the putty. Almost instantly, however, the silicone flows together and starts to rotate the driven shaft. This process of shearing and re-forming continues until both shafts are rotating at the same speed. By adjusting the pressure on the putty, it can be made to shear at any load, above which it will not have sufficient adhesion to drive. At the same time, the silicone will absorb torsional vibrations and sudden impulses. The operation of the flexible coupling is very similar, except that means are provided to compensate for the misalignment by displacing the soft silicone putty.

● *IMPROVED COLD-DRAWING SPEED*

In the cold-drawing of bars it has been found that drawing speed can be considerably increased by abandoning the conventional lime-coating technique and substituting a dry, thin-film lubricant coating. This lubricant consists of a granulated powder which contains waxes and fats of high melting point, in combination with a colloidal pigment. Containing in addition extreme-pressure and lubricating additives, the lubricant is held together in a matrix of regenerated cellulose, which provides adhesive properties. In practice, the hot pickled bars or rods are rinsed and then immersed in a tank containing the new lubricant for about five minutes. They are then drained and dried in air. External heating or baking is not required, as the residual heat retained in the bars is sufficient to dry the film coating, even under the most humid conditions. In this way an adherent semi-waxy film of about one thousandth of an inch in thickness is formed on the bars and, if required, the coated bars may be stored for several days without rusting or deterioration of the coating, as the film is not hygroscopic. During the draw an auxiliary lubricant is applied to the bars at the entrance to the dies. This lubricant is a low-viscosity, high film-strength drawing oil with properties selected in consideration of the chemical and physical properties of the base film. This auxiliary lubricant is highly effective in removing heat from dies, die holders, bar stock, and heat produced by deformation of the metal. Furthermore, its polar-active properties promote rapid spreading over the die surfaces and the film of primary lubricant on the metal surface.

● *IMPROVED BENDING PROPERTIES OF TITANIUM STRIP*

It has been found that the bending properties of titanium strip can be greatly improved by removing a few thousandths of an inch of surface metal which has become embrittled in annealing or hot rolling. Pickling in acid has been found to be an effective method of removing from 0·001 to 0·002 in. per surface, although bending properties are improved where surface metal is ground off. Experiments have been conducted to determine the causes for the improvement in ductility achieved. First of all, both pickling and grinding were found equally effective in improving ductility, and showed that the ductility of titanium is improved by the removal of surface layers by any means. Extensive X-ray studies were made of titanium strip rolled and annealed according to a variety of schedules, to determine what undesirable features of the metal are present in the metal surface. These might be oxygen- and or nitrogen-saturated metal resulting from annealing, or an undesirable orientation of material as a result of rolling. However, under no condition was it possible to find an orientation similar to that in the interior of the sheet. This, of course, discredited the idea that highly oriented surface layers were the major contributory factor in damaging bending properties. A series of experiments was made, in which a surface layer was removed by grinding prior to rolling the metal. Since rolling did not lead to the re-appearance of brittle surface layers, these experiments showed that the improved bending properties are due to the removal of oxygen- and or nitrogen-saturated surface layers, and this can be easily carried out by pickling to the depths mentioned above.

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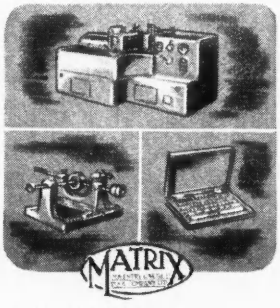

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